BBC

JAMES WEBB SPACE TELESCOPE FIRST IMAGES EXPLAINED

Science Focus

The psychology of
WORKING FROM HOME

Can we trust an
AI THAT CAN PREDICT CRIME?

How to pick
THE SAFEST SUNCREAM

EVERYTHING YOU EVER WANTED TO KNOW ABOUT
THE MULTIVERSE

SF
SCIENCEFOCUS.COM
#380 SUMMER 2022 US
UK £5.50 US $11.50 CAN $13.99
AUS $13.50 NZ $13.99

IN THIS ISSUE

Mars
Could a sample mission bring alien microbes to Earth?

Neuroscience
Why our brains enjoy art

Robots
Why we love some machines and hate others

FUJIFILM

X | GFX

MASTERS OF COLOUR

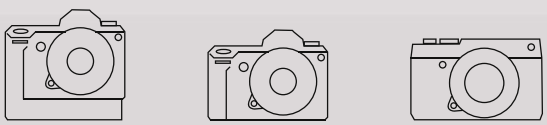
GFX 100S

Get more than full-frame. Unlock your creativity with the GFX100S

102-megapixel sensor and unique Fujifilm processing delivers the ultimate quality, resolution and colour reproduction

Five-axis IBIS and a sensor that's 1.7 times larger than full-frame, packed into a body that weighs only 900g

Professional-quality 4K/30p video in 10-bit F-Log or 12-bit Apple ProRes RAW from a 43.8x32.9mm sensor



GFX100 GFX100S GFX50R

FUJIFILM-X.COM

IMAGE TAKEN BY CHINA X-PHOTOGRAPHER JI GUO

Why does it feel so good to set the world to rights with a friend? →p84

FROM THE EDITOR

It finally happened. The James Webb Space Telescope (JWST) revealed its first image… after a short wait. The project took nearly 20 years to build and cost $10bn, making it one of the more expensive missions in recent history.

The image is, of course, astonishing. Take a grain of sand and hold it up at arm's length – that's the portion of sky the image covers. It's what's known as a deep-field image (essentially a long-exposure photo that tries to pick up the faintest, most-distant objects). But what's really cool about it is that the JWST, our most powerful telescope, is actually looking through another hugely powerful telescope, one that's created by a natural phenomenon. To be precise, the image shows a massive galaxy cluster named SMACS 0723 as it appeared 4.6 billion years ago. There's so much mass in this portion of space that it's warping space-time into a lens, bending and focusing light towards the sensor aboard the JWST. In effect, it's a telescope formed by gravity. You can see the warping in the shape of some of the galaxies – they look stretched and curved. These galaxies are actually behind the cluster in the centre.

It's just a taster what's to come, and that's the *really* exciting thing. Right now, the JWST is set to show us the Universe from a completely new perspective and, in doing so, will allow us to discover new worlds, new phenomena and even new laws of physics. In terms of discovery, this is a moment of unlimited potential. To discover more about the images and what they tell us, head to p16 where cosmologist Dr Katie Mack explains it all.

Daniel Bennett, Editor

WANT MORE? FOLLOW **SCIENCEFOCUS** ON FACEBOOK TWITTER PINTEREST INSTAGRAM

COVER: ANDY POTTS THIS PAGE: GETTY IMAGES X2, BBC, DANIEL BRIGHT

ON THE BBC THIS MONTH...

The Climate Question
Could we stop burning fossil fuels if we covered the Sahara with solar panels? An expert panel explores what easy wins there might be in the battle against climate change.
BBC World Service
25 July, 8pm

Sliced Bread
Greg Foot investigates the bold claims made by so-called 'wonder products', such as air fryers and manuka honey, to see if there is any science behind the hype.
Available on BBC Sounds

Unvaccinated
Prof Hannah Fry finds out why 8 per cent of the UK population are still not vaccinated against COVID-19, and sees whether some science can change their minds.
BBC Two
20 July, 9pm
Also available on BBC iPlayer

CONTRIBUTORS

PROF ISHANU CHATTOPADHYAY
An AI algorithm built in Ishanu's laboratory has been able to predict crimes before they happen. He explains how we might use it responsibly. →p28

ROBERT LEA
Comics and astrophysics are science writer Robert's passions. He takes us through the multiverse theories that have taken over pop culture in recent years. →p62

DR DEAN BURNETT
Dean, a neuroscientist and author of *The Idiot Brain,* breaks down what we know about productivity when it comes to working from home, and whether it's a poor substitute for the office. →p70

MIKA MCKINNON
Geophysicist and writer Mika reveals what some of the most astonishing rock formations on the planet can tell us about Earth's geological history. →p54

CONTACT US

Advertising
David.DSouza@ourmedia.co.uk
0117 300 8110
Letters for publication
reply@sciencefocus.com
Editorial enquiries
editorialenquiries@sciencefocus.com
0117 300 8755
Subscriptions
buysubscriptions.com/contactus
03330 162 113*
Other contacts
sciencefocus.com/contact

*UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am-5pm. If calling from overseas, please call +44 1604 973721. *BBC Science Focus* (ISSN 0966-4270) (USPS 015-160) is published 14 times a year (monthly with a Summer issue in July and a New Year issue in December) by Our Media Company, Bristol, Eagle House, Bristol, BS1 4ST. Distributed in the US by NPS Media Group, 2 Enterprise Drive, Suite 420, Shelton, CT 06484. Periodicals postage paid at Shelton, CT and additional mailing offices. POSTMASTER: Send address changes to *BBC Science Focus*, PO Box 37495, Boone, IA 50037-0495.

CONTENTS

REGULARS

06 EYE OPENER
Stunning pictures from around the world and off it.

12 CONVERSATION
The latest batch of letters and emails from our readers.

15 DISCOVERIES
The month's science news: James Webb Space Telescope releases its first images; the mites that have sex on your face could be going extinct; secrets of turtle ageing revealed; beautiful images of ancient deities uncovered on the walls of Egyptian temple; and a crime-fighting algorithm.

32 DR JULIA SHAW
Did you know that if you stimulate a particular part of the brain, your tastes in art will suddenly change? This issue, Julia sheds light on the intriguing science of neuroaesthetics.

34 DR KATE DARLING
Why do we look upon our robotic vacuum cleaners with affection and even give them names, but universally hate other forms of artificial intelligence? We're looking at you, Microsoft Clippy...

38 REALITY CHECK
The science behind the headlines. How do I choose the best suncream? Does electroconvulsive therapy work? Could bringing back samples from Mars contaminate the Earth with alien microbes?

45 INNOVATIONS
The latest tech and gadgets news.

79 Q&A
Our experts answer this month's intriguing questions. Did *T. rex* have feathers? Does blowing on a hot cup of tea actually do any good? Why can't marine animals survive in fresh water? Is Marmite good for you? What is Web3?

88 CROSSWORD
Give your brain a workout with our tough crossword.

88 NEXT MONTH
See what's coming up in the next issue of *BBC Science Focus*.

90 POPCORN SCIENCE
Could fire-breathing creatures really exist? And what chemistry would they need to harness?

52 SUBSCRIBE TODAY!

Get 3 issues for just £5 when you a subscribe to *BBC Science Focus*!

15 DISCOVERIES

Feast your eyes upon the first images from the James Webb Space Telescope.

38 REALITY CHECK

With the weather hotting up, what is the best way to keep your skin protected in the sunshine?

79 Q&A

FEATURES

54 FOR THOSE WHO LIKE TO ROCK
Take a trip around the world with geologist Mika McKinnon, as she explores some of the weirdest rock formations on Earth.

62 A MULTITUDE OF MULTIVERSES
Excitingly, scientists say that alternative universes are allowed by physics. We find out about the leading multiverse theories, and establish whether they could harbour an alternate version of you.

70 WORKING FROM HOME VS THE WORKPLACE: A SCIENTIFIC GUIDE
For more than two years, many of us have been working from home, at least sometimes. Has this made us happier and more productive than full-time office work?

54
FOR THOSE WHO LIKE TO ROCK

50
IDEAS WE LIKE...
Smart hiking boots that look pretty sci-fi.

62
HELING DENG

"ONE REASON THAT THE CONCEPT OF THE MULTIVERSE BECAME POPULAR IS THAT IT CAN NATURALLY ARISE FROM THE THEORY OF INFLATION"

WANT MORE?

Don't forget that *BBC Science Focus* is available on all major digital platforms. We have versions for Android, as well as an iOS app for the iPad and iPhone.

Can't wait until next month to get your fix of science and tech? Our website is packed with news, articles and Q&As to keep your brain satisfied.
sciencefocus.com

INSTANT GENIUS
Our bite-sized masterclass in podcast form. Find it wherever you listen to your podcasts.

LUNCHTIME GENIUS

A DAILY DOSE OF MENTAL REFRESHMENT DELIVERED STRAIGHT TO YOUR INBOX
Sign up to discover the latest news, views and breakthroughs from the *BBC Science Focus* team
www.sciencefocus.com/newsletter

EYE OPENER

Legend has it...

GRAN SASSO, ITALY

Current models suggest matter and antimatter should have been created in equal quantities in the Big Bang, but we are living in a Universe that is comprised mostly of matter. The LEGEND experiment is studying particles called neutrinos to find out why this is the case.

When a particle combines with its own antiparticle, they destroy each other and explode in a burst of energy. The antiparticle is like a mirror image of a particle: it has the same mass, but the opposite electric charge. LEGEND will investigate a type of radioactive decay called 'neutrinoless double beta decay', to explore the hypothesis that neutrinos, which have a tiny mass and no charge, are actually their own antiparticle. If this is the case, it would open up a route to help us understand the existence of matter over antimatter.

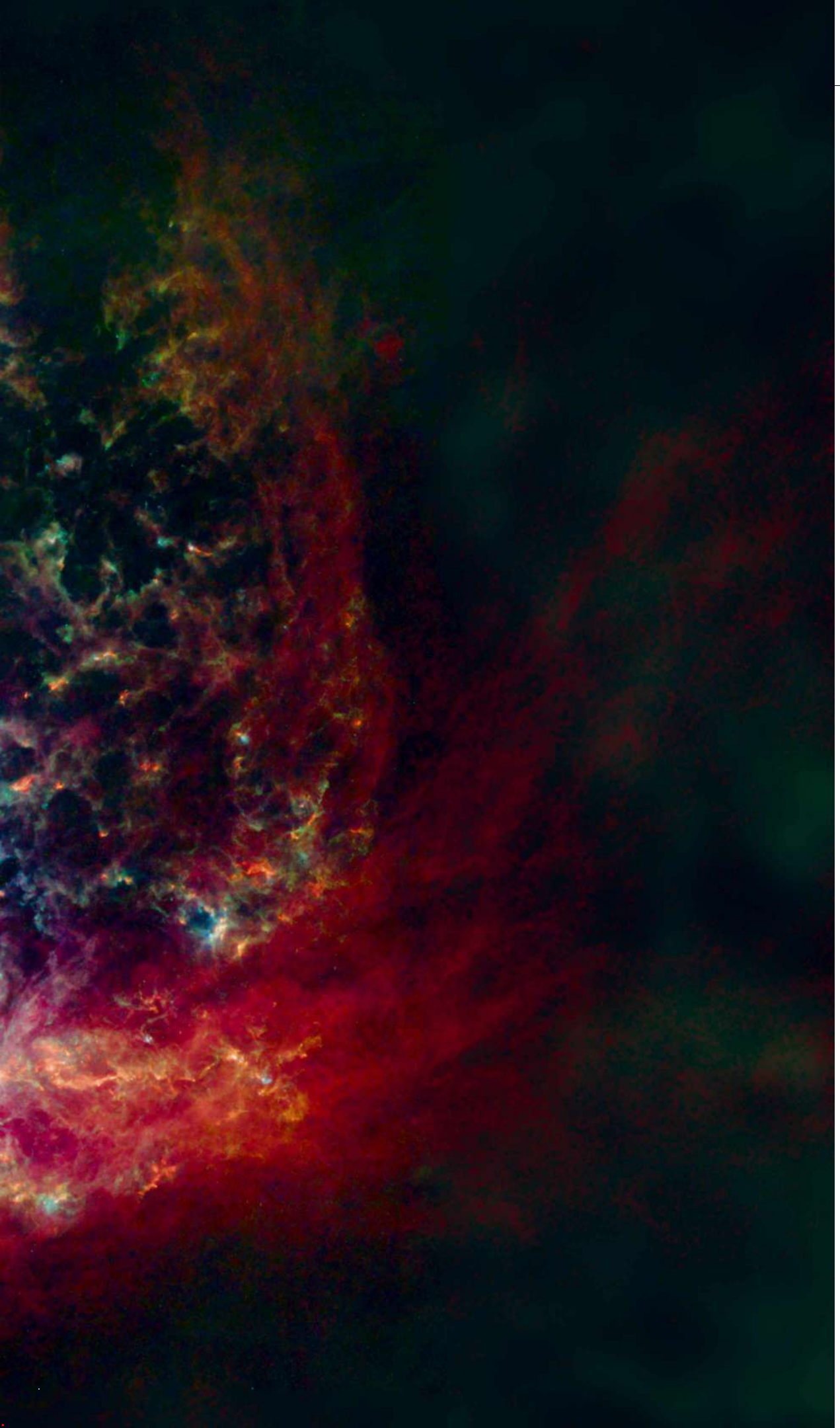
In the centre of the image is the LEGEND cryostat, into which the detector array will be placed. The cryostat lies inside a 590m^3 tank, which will be filled with water, to shield the experiment from external influences.

ENRICO SACCHETTI/NATIONAL LABORATORY OF GRAN SASSO

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS



EYE OPENER

Rainbow bright

LARGE MAGELLANIC CLOUD

Less than 160,000 light-years away from Earth is the Large Magellanic Cloud, a satellite galaxy of the Milky Way.

This incredible infrared-radio image, taken by the Herschel Space Observatory, peers through murky clouds to reveal the thermal glow of expanses of dust, undetectable to the human eye. Hydrogen gas, the most common element in the Universe, is shown in red.

The bubbles of empty space indicate regions where stars have recently formed. Intense winds from these newborn stars have blown away surrounding dust and gases, leaving an accumulation of cool dust around the edges, shown in green. Warmer dust, potentially where stars are forming, is shown in blue.

"These improved Herschel images show us that the dust 'ecosystems' in these galaxies are very dynamic," says Christopher Clark, an astronomer at the Space Science Telescope Institute.

ESA/NASA/JPL-CALTECH/STSCL

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS

EYE OPENER

Tardis tunnel

MASSACHUSETTS, USA

This giant fan is the heart of the new and improved Wright Brothers Wind Tunnel at the Massachusetts Institute of Technology (MIT). Said to be the most advanced academic wind tunnel in the US, it stands on the same site as the original Wright Brothers Wind Tunnel, which opened in 1938. The fan in that first wind tunnel was four metres wide and had six blades. This new one has 17 blades and a diameter of almost five metres. It's capable of generating wind speeds of up to 370km/h (230mph), compared to the original's 240km/h (150mph), while using less power and creating less noise than its predecessor.

The researchers at this new facility have managed to cram this bigger, more powerful fan into a footprint no bigger than that of the original Wind Tunnel building. This mind-boggling feat was achieved thanks, in part, to diffusers, screened turning vanes and specially designed tips on the fan blades, which control the air circulating around the comparatively small space.

ADAM GLANZMAN/MIT

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

reply@sciencefocus.com
BBC Science Focus, Eagle House, Bristol, BS1 4ST
@sciencefocus
www.facebook.com/sciencefocus
@bbcsciencefocus

LETTER OF THE MONTH

Women and physics

After reading your article on women and physics (June, p42), I kept thinking about my own experience. My physics teacher was a woman, and she inspired me to study physics at Nottingham University. After becoming an engineer, I began to realise I was working in a man's world. The only other women I met at work were secretaries, or worked in the typing pool. Once my younger child was in junior school, I retrained as a teacher and started working at a local comprehensive, where I hoped to inspire my pupils to study physics. For the 12 years I worked there, I was the only female physics teacher. I was promoted to head of science and longed to appoint another female physics teacher, but it was difficult to find *any* candidates (male or female), so much of physics had to be taught by non-specialists. I think that if we want to encourage more pupils, especially girls, to study physics, then we need to encourage more physics graduates, especially girls, to become teachers. There is a general feeling that physics is a difficult subject, usually studied by boffins. If physics is taught by enthusiastic, specialist physicists, more pupils might choose to study the subject and this, in turn, would help to stop this fear of physics being 'hard'. Perhaps the answer is to allow more subjects to be studied at A-Level. More pupils might decide to 'give physics a go', while still studying 'safer' subjects, so they are more confident of achieving the points required for further study.

Barbara Atkinson, East Sussex

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **bundle of sci-fi and fantasy books from Pan Macmillan**. The prize includes *A Memory Called Empire* by Arkady Martine, *A Desolation Called Peace* by Arkady Martine, *The Kaiju Preservation Society* by John Scalzi, *Shards Of Earth* by Adrian Tchaikovsky, and *Rabbits* by Terry Miles. **panmacmillan.com**

WORTH £62.95

On the metaverse

[The metaverse could cause] another mental illness, self-inflicted, that will eventually consume enormous resources in an attempt to mitigate or cure it. I have spent most of my 89 years striving to separate hallucinations from reality and I don't intend to give up that effort now. I do not think I will be around when the consequences of this latest folly become painfully realised, but I think they will be profound and dire!

Kenneth Healy, Michigan

Inflating evolution

Your article on real-life balloon animals (April, p44) got me thinking about how evolution works. Does it act in small steps, or larger leaps? If it's in small steps, do these steps (such as a slightly larger vocal sac) offer enough of an evolutionary advantage to get selected?

Al Bennett, Bristol

It's a good question. For this kind of adaptation, I'd argue it's small steps all the way. As larger vocal sacs propel sounds further, any population where individuals show variation

Vocal sacs: a small step or big leap for evolution?

"FREE CAKE IS A STRANGE THING FOR PEOPLE TO GET UPSET ABOUT, BUT IT ILLUSTRATES HOW ATTEMPTS TO 'HUMANISE' A ROBOT CAN BACKFIRE"

DR KATE DARLING, P34

The asteroid that smashed into Earth and wiped out the dinos may have been the size of Everest

ALAMY, GETTY IMAGES X2

(even if only a mere matter of millimetres) in the sizes of vocal sacs would see winners and losers, genetically speaking, given enough time. Like cogs grinding in a machine, natural selection sets to work on populations until, theoretically, opposing factors (such as energy budgets) begin to kick in.
Jules Howard, zoologist

Making mountains

My previous readings suggested that the asteroid that hit 65 million years ago had a maximum diameter of around 50 miles, or more likely around nine miles, or was that kilometres? Prof Steve Brusatte (June, p70) states that the asteroid was the size of Mount Everest. Are we looking at the height of Mount Everest from sea level? Also, what are the boundaries that decide which part of the Himalayas constitute Mount Everest?
Rodney Minns, Hampshire

Recent studies on the Chicxulub Crater left behind by the asteroid indicate that it was approximately six miles in diameter, or around 10 kilometres. This is roughly the size of Mount Everest. The comparison is not meant to be exact, but a ballpark estimate to put the general size of the asteroid into context.
Prof Steve Brusatte, palaeontologist

Reference list?

I'm a long-time fan of the magazine and always look forward to it landing on my doorstep every month. *BBC Science Focus* does an excellent job of making study results digestible to people lacking expertise in the relevant area. When you discuss a study in an article, would it be possible to provide a reference or URL for the original paper, for those nerdy few of us who want to explore the subject in more depth? I appreciate they're often paywalled, but not always, and even being able to look up the abstract would allow those so inclined to take a deeper dive into the research. This could be in print, or even a monthly reference list published on your website for each issue.
Iain Kennedy, Dundee

THE TEAM

EDITORIAL
Editor Daniel Benneff
Managing editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Online staff writer Sara Rigby
Staff writers Alex Hughes, Holly Spanner
Editorial assistant Amy Barreff

ART
Art editor Joe Eden
Picture editor James Cutmore

CONTRIBUTORS
Claire Asher, Scoff Balmer, Rob Banino, Hayley Benneff, Peter Bentley, Steve Boswell, Daniel Bright, Steve Brusaffe, Dean Burneff, Anson Chan, Alistair Charlton, Stuart Clark, Kate Darling, Emma Davies, Mark Frudd, Christian Jarreff, Stephen Kelly, Pete Lawrence, Robert Lea, Katie Mack, Nish Manek, Mika McKinnon, Dann Mitchell, Helen Pilcher, Andy Poffs, Jenny Price, Helen Scales, Julia Shaw, Colin Stuart, Luis Villazon, Joe Waldron, Myriam Wares.

ADVERTISING & MARKETING
Business development manager David D'Souza
Newstrade manager Rob Brock
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane

MOBILE
Head of apps and digital edition marketing Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION
Production director Sarah Powell
Production coordinator Georgia Tolley
Ad services manager Paul Thornton
Ad designer Julia Young

PUBLISHING
Publisher Andrew Davies
Group managing director Andy Marshall
CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING
Chair, editorial review boards Nicholas Breff
Managing director, consumer products and licensing Stephen Davies
Director, magazines and consumer products Mandy Thwaites
Compliance manager Cameron McEwan
UK publishing coordinator Eva Abramik
Contact UK.Publishing@bbc.com
www.bbcstudios.com

EDITORIAL COMPLAINTS
editorialcomplaints@immediate.co.uk

ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £77; Europe & Eire £92.54;
Rest of World £102.90.

Audit Bureau of Circulations
50,142 (combined, Jan-Dec 2021)

BBC Science Focus Magazine is published by Our Media Ltd (an Immediate Group Company), under licence from BBC Studios who help fund new BBC programmes.

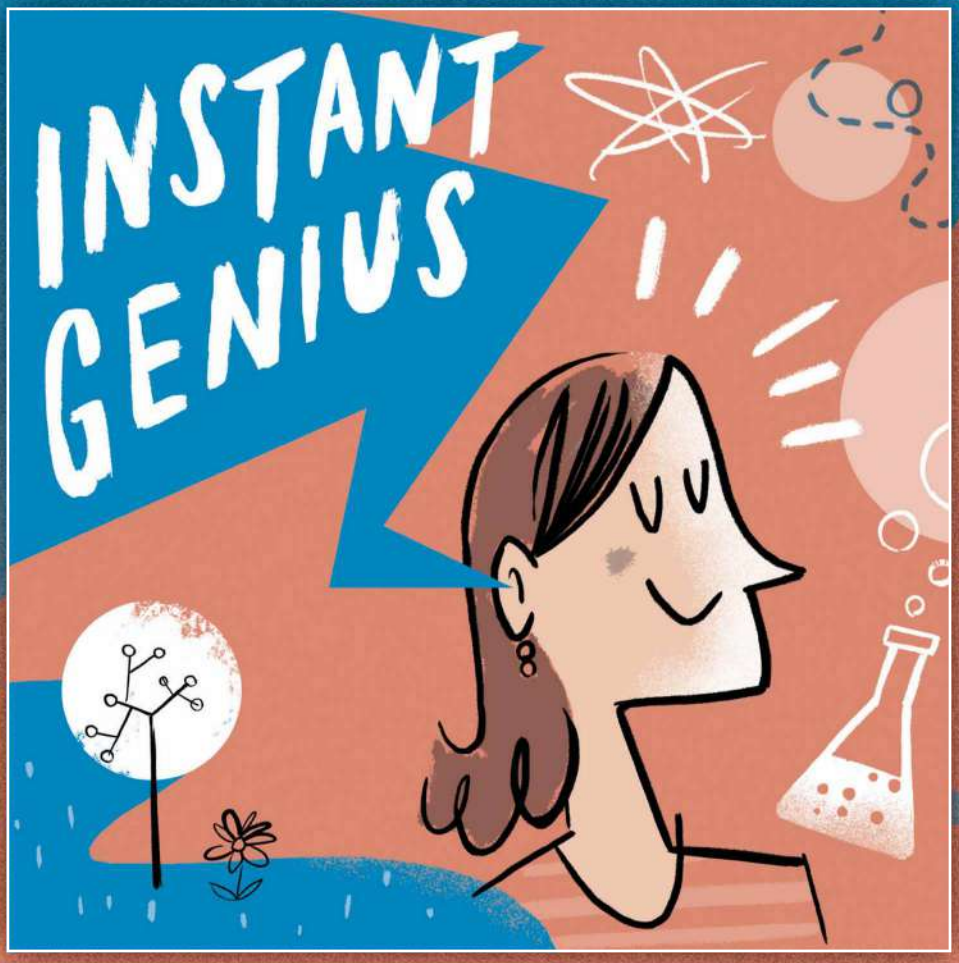
© Our Media Ltd 2022. All rights reserved. Printed by William Gibbons Ltd.

Our Media Ltd accepts no responsibility in respect of products or services obtained through advertisements carried in this magazine.

recycle
When you have finished with this magazine please recycle it.

DON'T JUST READ THIS MAGAZINE... LISTEN TO US TOO

The all-new weekly podcast from the team behind *BBC Science Focus*



FEATURING

BRAIN MYTHS
with ***Dr Lisa Feldman-Barrett***

ALGAE
with ***Ruth Kassinger***

THE METAVERSE
with ***Prof David Reid***

ANCIENT MAMMALS
with ***Dr Elsa Panciroli***

DISCOVERIES

"This might suggest that they also could have simple but important beneficial roles"

Dr Henk Braig on face mites **p22**

SPACE

A NEW VIEW

First images from the James Webb Space Telescope **p16**

BIOLOGY

FREAKY FACIAL

Mites that live on your face may be going extinct **p22**

AGEING

TALE OF A TURTLE

Secrets of reptile ageing revealed **p24**

NEUROLOGY

NOT A DISORDER

Dyslexics may be adapted towards exploration **p25**

ARCHAEOLOGY

HIDDEN WORLD

Deities revealed in Egyptian temple **p26**

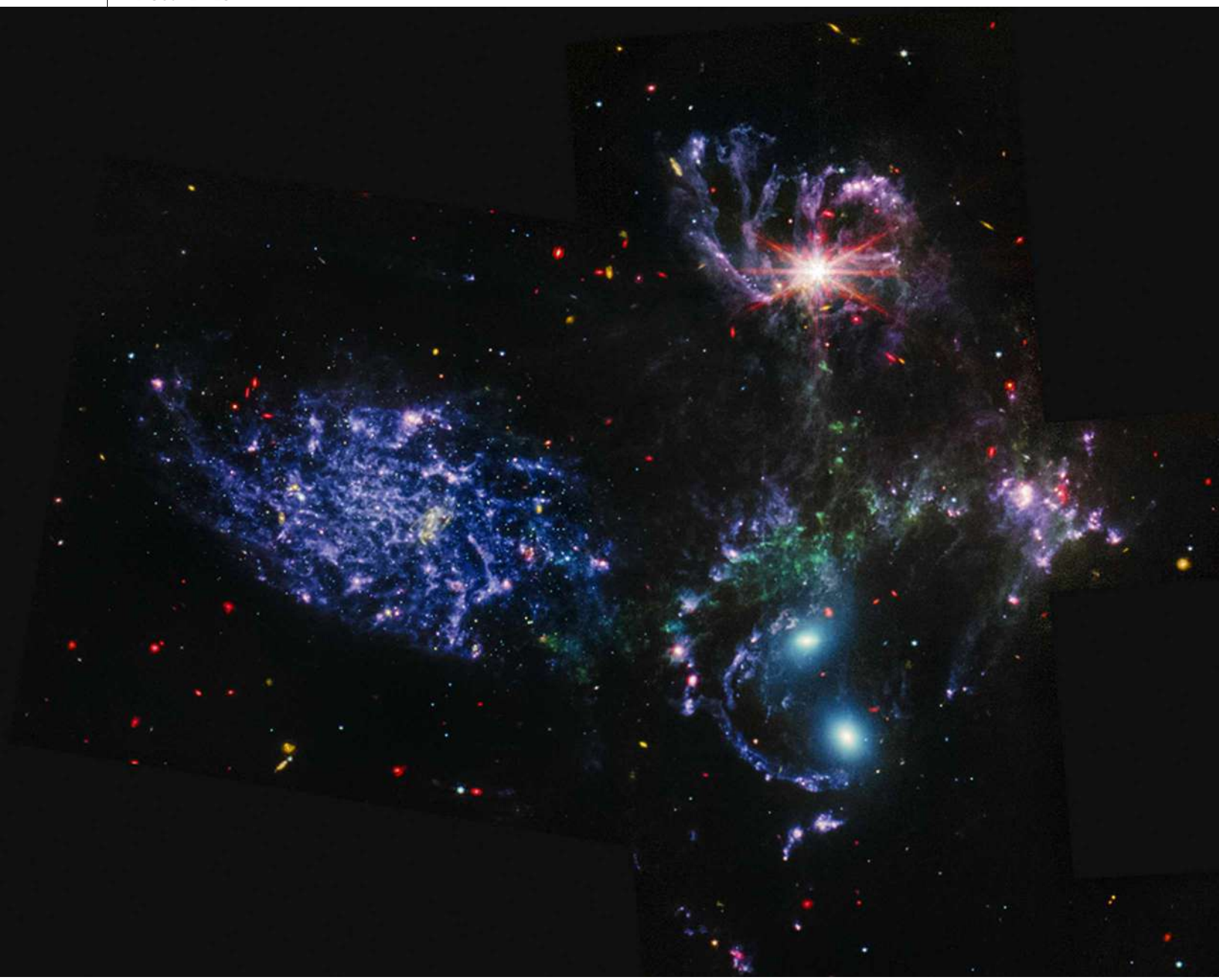
MACHINE LEARNING

CRIME STOPPER

Algorithm predicts crimes before they happen **p28**

The first image from the James Webb Space Telescope captured light from some of the most distant galaxies we've ever seen, letting us look billions of years into the Universe's past

NASA/ESA/CSA/STScI



DR KATIE MACK
(@AstroKatie)
Katie holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute.

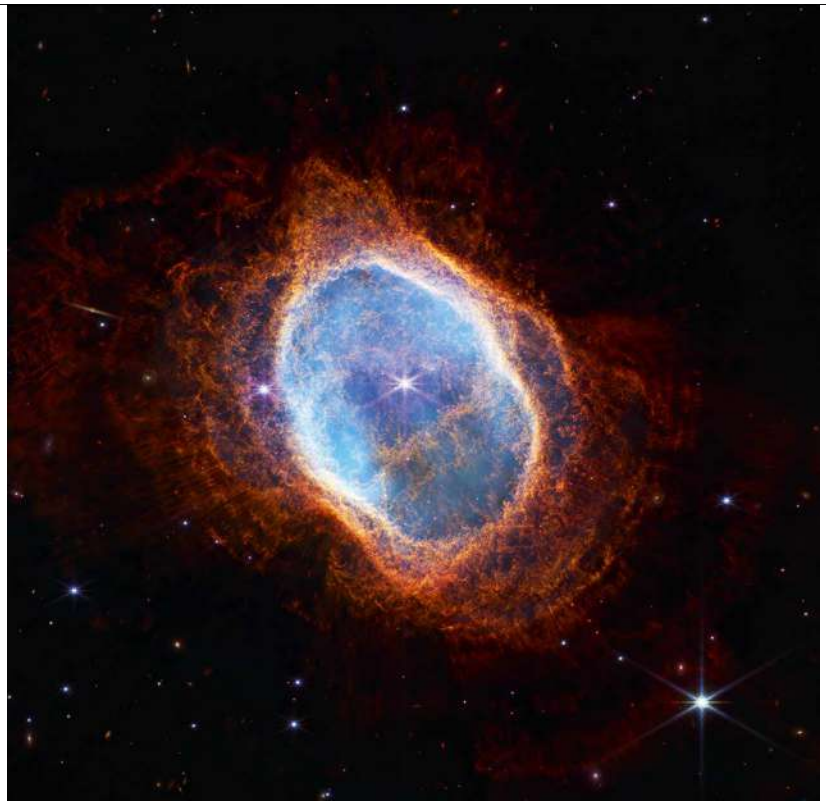
COMMENT

JAMES WEBB SPACE TELESCOPE SHOWS US THE UNIVERSE IN A NEW LIGHT

These images will kick-start a new era in space exploration

On my phone is a slightly blurry photo of a distant, unnamed galaxy. It's a little white smudge with spiral arms like sheep's wool fluff – one galaxy among thousands of others in the James Webb Space Telescope's (JWST) new breathtakingly detailed image of the distant cosmos – and I can't stop staring at it. There is nothing especially remarkable about this little white swirl; it's not the largest or sharpest or most perfectly rendered or in any way most interesting galaxy in the image. But before JWST, no human had ever really seen it. I am seeing it now, fully and completely, and it is beautiful.

JWST is going to show us a lot of things we've never seen before. The selection of images (and one spectrum) in the telescope's science image debut were chosen to showcase all the ways in which this project will



NASA/ESA/CSA/STScI X3

fundamentally change our view and understanding of the Universe.

The first picture to be released, in a special presentation with US President Joe Biden on Monday night, brought us a giant galaxy cluster embedded in a skyscape scattered with enough distant background galaxies – including my own tiny spiral – to rival the deepest of the Hubble Deep Fields. What took Hubble a week and a half, JWST did "before breakfast", according to Dr Jane Rigby, JWST's operations project scientist.

JWST is about 100 times more sensitive than Hubble, owing to its giant mirror, sensitive cameras, and ability to capture the infrared light emitted by the Universe's most distant objects. The image depicts a sky teeming with bright eight-pointed stars (the points are artefacts of the light waves interacting with the telescope's architecture) and galaxies in all shapes and sizes, along with odd smudges and arcs that seem to be encircling the central cluster. Those curving smudges are the light from ordinary galaxies far in the distance, behind the cluster, distorted by its immense gravity. This effect, known as gravitational lensing, both stretches and magnifies the images of background objects, allowing the telescope to see things that would otherwise be both hidden and too dim to detect, extending its reach even further. This is the deepest and sharpest infrared image of the cosmos ever taken, and JWST barely broke a sweat.

As a cosmologist who studies the early Universe, I expected to be enthralled by the deep-field image. But it was just the preview. In a long press event on Tuesday morning, interspersed with vignettes to highlight as many as possible of the 20,000 people who helped make JWST a reality, the team presented spectral data of clouds and water vapour in the atmosphere of a planet orbiting a distant star and handed us three more mind-blowing images. In what I suspect will be a trend with a telescope this powerful, each image contained some feature or detail that rendered it not just a sharper view of a known object, but a shift in our fundamental understanding.

"This project will fundamentally change our view and understanding of the Universe"

Stephan's Quintet is a group of four galaxies bound together by gravity, plus one foreground interloper. The four are slowly spiralling together, pulling out long streamers of stars and creating bursts of new star formation as the gas they contain collides. By extending its view far beyond the range of visible light into the infrared, JWST is able to show us the tendrils of dust created by those bright-burning new stars, while simultaneously teasing out and analysing ➔

LEFT Stephan's Quintet, a group of four galaxies bound together by gravity, plus one foreground interloper, taken with the Mid-Infrared Instrument (MIRI). MIRI reveals never-before-seen shock waves and tidal tails

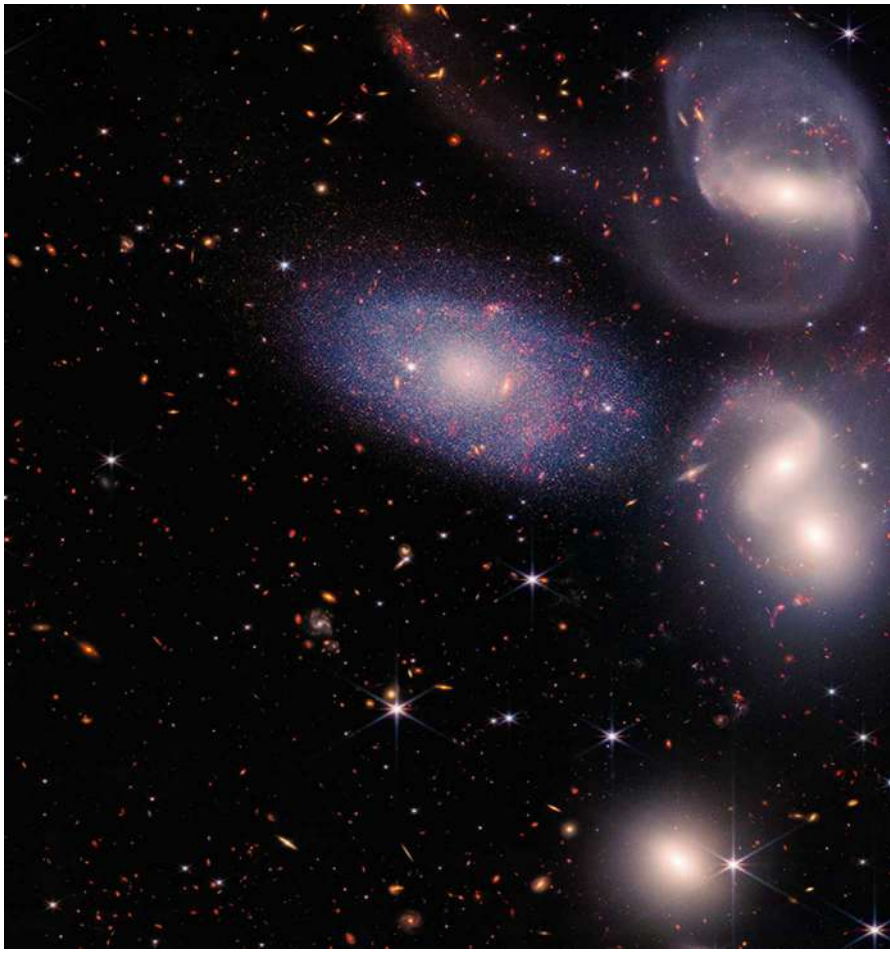
ABOVE LEFT The Southern Ring Nebula, with clouds of gas and dust

ABOVE RIGHT The Southern Ring Nebula, imaged using MIRI, reveals the binary star system at the centre

OVERLEAF The towering cosmic clifts of the Carina Nebula, where stars are born

NASA/ESA/CSA/STScI

“fi is is our cosmic origin story, viewed 8,000 light-years away, in another part of the Galaxy, but, nonetheless, entirely ours”



a streamer of hot gas flowing out from the vicinity of the supermassive black hole in the centre of one of the galaxies. With that extra data, we’re not just studying these individual galaxies; we’re learning about how galaxies and their black holes form and grow.

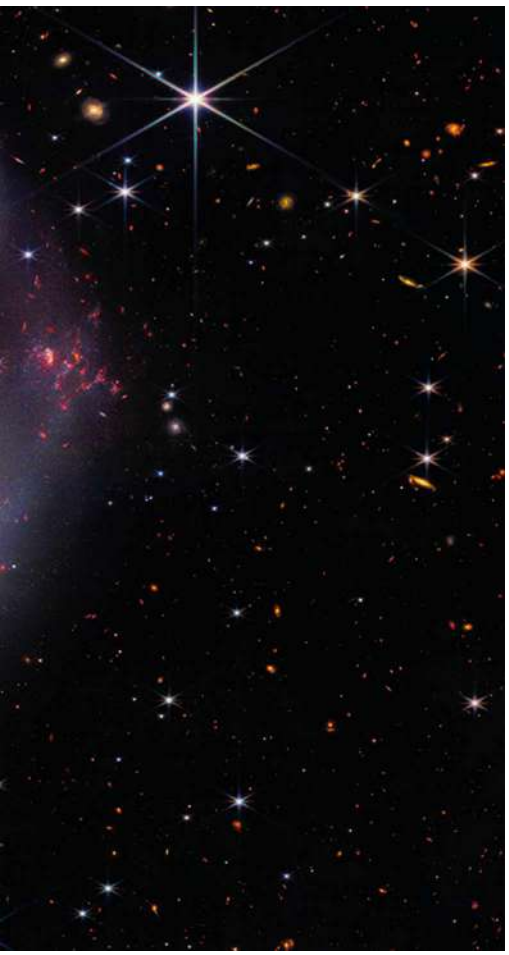
Closer to home, the Southern Ring Nebula is a bubble of fluorescing gas ejected by a dying star in its centre. In JWST’s near-infrared view, we see wispy shells and streams of gas and dust surrounding the glow of the hot gas, lit by a bright pinprick in its centre. But by also using mid-infrared light – longer wavelengths, capable of better penetrating the gas – JWST shows us that the pinprick is actually split in two, with one dot dimmer and redder than the other. JWST can distinguish the two stars of the binary system, showing us which of them is the dying white dwarf star, shrouded in dust, and which is its brighter blue companion. Even in this image, distant background galaxies can be spotted in the darkness surrounding the nebula, one prominent edge-on disc galaxy rendered in enough detail for us to see its bright central core and dust lanes.

I didn’t expect to be affected by the final image, a section of a stellar nursery called the Carina Nebula (see previous page). Nebulae are pretty, of course, but I’m a cosmologist. Give me the galaxies, the black holes, the warped space-time. Stars are commonplace. Our Galaxy is full of them. What is another dust cloud, when you have the entire cosmos stretching before you?

I was wrong, of course.

JWST’s view of the Carina Nebula is astounding. In a pre-release press conference, Pam Melroy, NASA deputy administrator and retired astronaut, said, “What I have seen just moved me, as a scientist, as an engineer, and as a human being.” I’m not certain which of the images she was referring to, but my money would be on the Carina Nebula.

It’s not just that it’s beautiful. In this image, we see dusty, gaseous tendrils being slowly carved away by



ABOVE The capabilities of the telescope's Near-Infrared Camera (NIRCam) and MIRI, created this view of the Carina Nebula

LEFT Here, Stephan's Quintet has been imaged with NIRCam

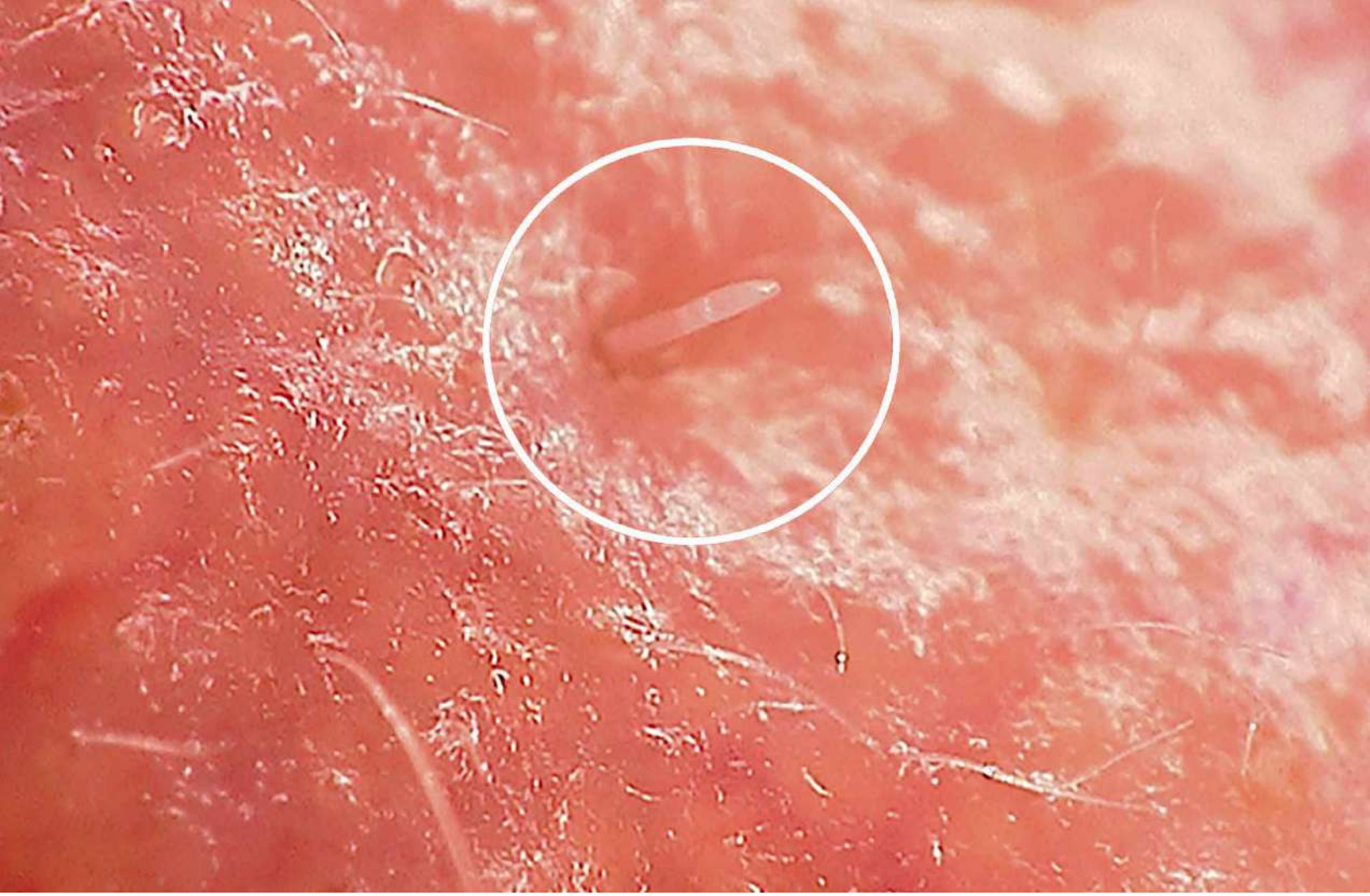
NASA/ESA/CSA/STSCI X2

the radiation of bright nearby stars, while within their depths protostars are just beginning to form. Where Hubble's view showed us the edges of the clouds, JWST lets us peer within, to watch the process of creation as it happens, to see, like never before, how new light is born from the stuff of the stars.

We came from that. We are made of that. This is our cosmic origin story, viewed 8,000 light-years away, in another part of the Galaxy, but, nonetheless, entirely ours.

The images in this first data release were from JWST's first week as a fully functioning science instrument. By the time this issue of *BBC Science Focus* goes on sale, we should have new views of our Solar System. In a few weeks, we'll have data from countless untouched corners of the cosmos. In a few years, I fully expect our understanding of stars and galaxies and the evolution of the Universe will be completely and irrevocably changed.

In the meantime, we all have a lot to process. The JWST team continues to schedule observations, download data, and maintain the engineering marvel that is this new and powerful machine. Observational astronomers around the world are analysing these first images to tease out new insights into their favourite astrophysical processes. And I, a theorist whose professional life revolves around equations and lines of code, am still staring at that little fluffy galaxy, wondering if anyone living in it has seen the Universe as we humans have today, and if they know how beautiful their home looks from afar.



A *Demodex folliculorum* mite (circled) inside a human follicle, as viewed under a microscope

UNIVERSITY OF READING, GETTY IMAGES

BIOLOGY

THE TINY MITES THAT HAVE SEX ON YOUR FACE ARE CLOSE TO EXTINCTION

The 0.3mm critters are just about visible to the human eye, and they're crawling all over your body as you sleep

Microscopic mites that live inside the pores of your skin are using the oils you produce to fuel their 'all-night' mating sessions – and that's actually a good thing. Once blamed for conditions like acne, rosacea and itchy scalps, these late-night lovers might actually be keeping our pores unblocked and free of the oils that contribute to skin problems. In fact, as the tiny mites do us more good than harm, they could be considered as much a part of our daily lives as the bacteria living in our gut.

Now, though, research from Bangor University and the University of Reading suggests that the tiny *Demodex folliculorum* mites might be under threat. This first-ever study of the mites' DNA has revealed that their ancient relationship with humans has contributed to the loss of much of the organisms' genetic variety. Living in the follicles, particularly around the face and nipples, has left them so isolated that they're approaching an 'evolutionary dead-end'.

The mites are passed on from mother to baby during childbirth and early life, and do not appear to transfer between adult humans with close contact. This means there are few opportunities for mite-mingling events, so mating pairs have passed on the same genes for millions of years, and shed the ones that were unnecessary.

"We found these mites have a different arrangement of body part genes to other similar species due

to them adapting to a sheltered life inside pores. These changes to their DNA have resulted in some unusual body features and behaviours," said the University of Reading's Dr Alejandra Perotti, who co-led the research.

For example, this gene reduction is part of the reason for their nocturnal behaviour. At some point, the mites lost the gene to produce melatonin, which is the chemical that nocturnal animals use to keep themselves awake at night. Luckily for the mites, melatonin is produced by glands on our skin at night, which they use to fuel their mating sessions.

Despite the fact the *Demodex* mites have had a relationship with us for millions of years, they are effectively on the path to extinction. Over the generations, the differences in the mites' DNA have become smaller and smaller. Someday, the gene pool will be so small, they may become extinct.

The genetic analysis also dispelled one long-standing idea about the mites: that they don't have anuses and hold onto all their faeces throughout their lifetime (a short two or three weeks) until they die. This dermo-dumping, researchers once supposed, could cause skin inflammation and problems like acne. But the *Demodex* mites don't deserve such a bad reputation.

"Mites have been blamed for a lot of things," said Bangor University's Dr Henk Braig, co-lead author of the new study. "[But their] long association with humans might suggest that they also could have simple but important beneficial roles, for example, in keeping the pores in our face unplugged."

"fi ese changes to their DNA have resulted in some unusual body features and behaviours"

Though the mites have been previously thought of as parasites, Braig and colleagues are pushing for a reassessment of their role in our lives. Their help in keeping our skin healthy means we could consider them one of our symbionts – a lifelong partnership between two different species that benefits both.

Can we prevent their loss? It may be too late.

"I think that we cannot stop nature, and we shouldn't," said Perotti. "However, [our] healthy skin should suffice to maintain healthy populations for generations to come."

CULTURE

WOMEN GIVEN LESS CREDIT THAN MEN FOR RESEARCH

Dataset detailing the article attributions of university researchers reveals significant gender gap

Women who work on scientific projects are 13 per cent less likely to be named as authors in research papers, a study carried out by researchers at New York University and Ohio State University has found.

The team used data taken from the UMETRICS project that was compiled by the Institute for Research on Innovation and Science. It contains information on more than 125,000 researchers who worked on almost 10,000 projects between 2013 and 2016. They found that the gender gap was present at every level, but it was particularly evident for researchers in the early stages of their careers. Just 15 per cent of female grad students were attributed as authors of projects they worked on, compared to 21 per cent of male students. The effect was seen across all areas of study.

"There is a clear gap between the rate at which women and men are named as co-authors on publications. The gap is strong, persistent and independent of the research field," said study co-author Prof Julia Lane, of New York University.

A survey of more than 2,400 researchers carried out alongside the analysis found that 43 per cent of women said they'd been excluded from a paper to which they had contributed, compared with 38 per cent of men. Many respondents also noted that they felt minorities and foreign-born scientists were at a similar disadvantage.

The findings could inform new policies to increase diversity in science, the researchers say.

AGEING

TURTLES CAN ALMOST STOP AGEING WHY CAN'T WE?

Researchers studying slow-ageing animals are beginning to understand why these creatures are able to live longer than us

Research suggests that some reptile species barely seem to age, despite growing older

Some cold-blooded animals can slow their ageing so much that they're essentially not ageing at all, according to the findings of the most comprehensive study of ageing to date. Published recently in the journal *Science*, the study was carried out by an international team of 114 scientists at Penn State and Northeastern Illinois University and involved 77 species of reptiles and amphibians. The team hopes that by studying these animals they can gain insights that could lead to treatments for age-related conditions in humans.

During the study, the team found evidence that turtles, crocodiles and salamanders all aged so slowly that their lifespans are longer than would be expected for animals of their sizes. In fact, some turtles aged so slowly that the team concluded they experienced 'negligible ageing', where their bodies don't age as they grow older.

This doesn't mean the turtles are immortal, only that their chance of dying isn't related to their age – unlike in humans, where our likelihood of dying increases the older we get.

"Negligible ageing means that if an animal's chance of dying in a year is 1 per cent at age 10, if it's alive at 100 years, its chance of dying is still 1 per cent," said Prof David Miller, an author of the new study. "By contrast, in females in the US, the risk of dying in a year is about 1 in 2,500 [0.04 per cent] at age 10 and 1 in 24 [around 4 per cent] at age 80."

"Some turtles aged so slowly that they experienced 'negligible ageing'"

The team also found that animals with built-in physical or chemical protections, such as hard shells, tough spines, or venomous bites, aged more slowly and lived longer than animals that didn't. As these features affect an animal's chance of dying, they likely influenced how the species evolved.

"For the species we looked at, having protective adaptations, being larger and taking longer to mature are all characteristics of species that age slower," said Miller. "These [traits] all affect mortality, and likely shape how evolution selects for physiological adaptations [in the animal] that limits ageing."

While these characteristics offer animals protection from predators, they can't always safeguard against threats like climate change and habitat loss. An animal's longevity can have other advantages, however, such as helping them endure and overcome challenges.

For example, one species in the study was shown to grow more slowly during hard times. The western terrestrial garter snake, *Thamnophis elegans*, was able to slow its growth when food supplies were unreliable. "This allows them to weather droughts that reduce the availability of their prey," said Miller.

Understanding the evolution and impact of protective traits in animals could bring us closer to understanding human ageing, and point towards new treatments and medicines for ailments related to the ageing process.

"We believe that turtles and other slow-ageing reptiles can be a model for learning about the physiological and genetic processes that underlie ageing [across all animals]," said Miller. "Turtles and some of the longer lived reptiles we studied share some characteristics with humans. Like humans, they take a long time to mature, their external sources of mortality are lower than most species and they're long lived."

BETH A REINKE/NORTHEASTERN ILLINOIS UNIVERSITY, GETTY IMAGES

NEUROLOGY

DYSLEXIA ISN'T A DISORDER, IT'S ESSENTIAL TO HOW OUR SPECIES ADAPTS, SAY RESEARCHERS

People with dyslexia have brains that are geared towards exploring the unknown, a trait that's been crucial to the survival and success of humans

Dyslexia should be considered a difference, not a disorder, researchers at the University of Cambridge say. This is evidenced by studies that show that people with dyslexia have brains that are specialised to explore the unknown and think in terms of the bigger picture.

The strengths of the dyslexic brain could have evolved as humans adapted to changing culture. To survive, we needed to learn skills and acquire habits, but we also needed to be creative and find novel solutions through exploration. In their new study, Dr Helen Taylor and Dr Martin Vestergaard say that this resulted in a trade-off whereby some people specialised in exploiting learned information, while others focused on discovery and invention.

Dyslexia can make reading and writing difficult, but is also associated with skills such as creative thinking and problem solving

"In many other fields of research it's understood that adaptive systems – be they organisations, the brain or a beehive – need to achieve a balance between the extent to which they explore and exploit in order to adapt and survive," said Taylor, who studies cognition and human evolution.

Studies have shown that people with dyslexia are less efficient at procedural learning than non-dyslexic people, said Taylor, and this has positives and negatives for both groups.

"Learning to read, write or play the piano are all skills that are dependent upon procedural memory; once learned, the skills can be processed automatically and rapidly," Taylor added. "However, once a skill becomes automatic, you're essentially exploiting the same information again and again. Conversely, if an individual has difficulty acquiring automaticity, they retain conscious awareness of the process. The upside is that a skill or process can still be improved."

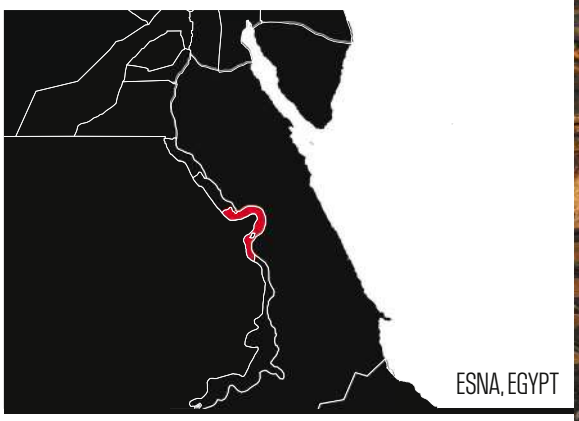
Dyslexia has long been viewed through a negative lens. It has been called a developmental disorder, learning disability or learning difficulty. Instead, the distinction between dyslexic and non-dyslexic brains should be framed simply as a difference, said Taylor.

"We all possess difficulties in areas that are other people's strengths. It's just unfortunate that in the case of people with dyslexia their difficulties are continually highlighted, in part due to the nature of education and also to the importance of reading and writing in our culture."

By re-examining past studies in psychology and neuroscience, Taylor and Vestergaard found fundamental differences in how the dyslexic brain is wired. Particularly, the way the brain organises its neurons and pathways differs depending on whether the brain is better at global, 'big picture' thinking or local, 'detail-oriented' thinking. Individuals with dyslexia were shown to have more long-range connections and fewer local connections.

Because these ways of thinking evolved as a trade-off, they work best in collaboration, said Taylor. Bringing explorative, global-thinking brains together with exploitative, local-thinking brains leads to solutions that couldn't be imagined by an individual, or even a group of similar people.

In reframing dyslexia as a difference, society can benefit from more innovative solutions, said Taylor. "It's important to emphasise that people with dyslexia still face a lot of difficulties, but the difficulties exist because of the environment and an emphasis on rote learning and reading and writing. [Instead, we could] nurture 'explorative learning' – learning through discovery, invention and creativity, which would work more to their strengths."



EGYPT

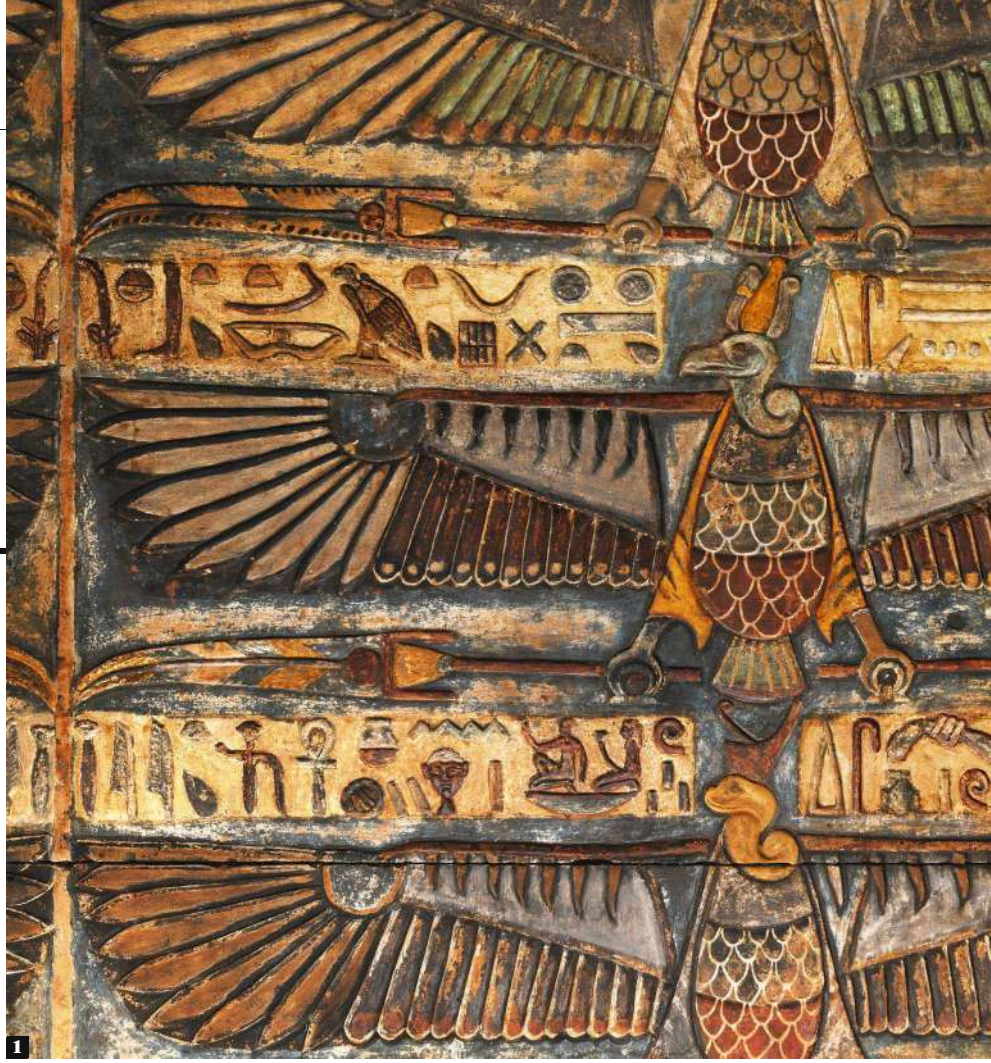
VIBRANT FRESCOES UNCOVERED IN EGYPTIAN TEMPLE SHOW DEPICTIONS OF ANCIENT DEITIES

German and Egyptian researchers have uncovered paintings and inscriptions on the walls and ceilings of the Temple of Khnum at Esna, near Luxor in Egypt.

The images, which feature depictions of several deities, were covered in dirt and soot for almost 2,000 years, which has helped to preserve them in immaculate detail.

"Temples and ancient depictions of the gods were often painted in brilliant colours, but these have usually faded or even disappeared totally as a result of external influences," said lead researcher Prof Christian Leitz, of the University of Tübingen, Germany. "For the first time we can see all the decorative elements in relation to one another."

After beginning work in 2018, the researchers have now cleaned half of the temple's ceilings and eight of its 18 columns.


1

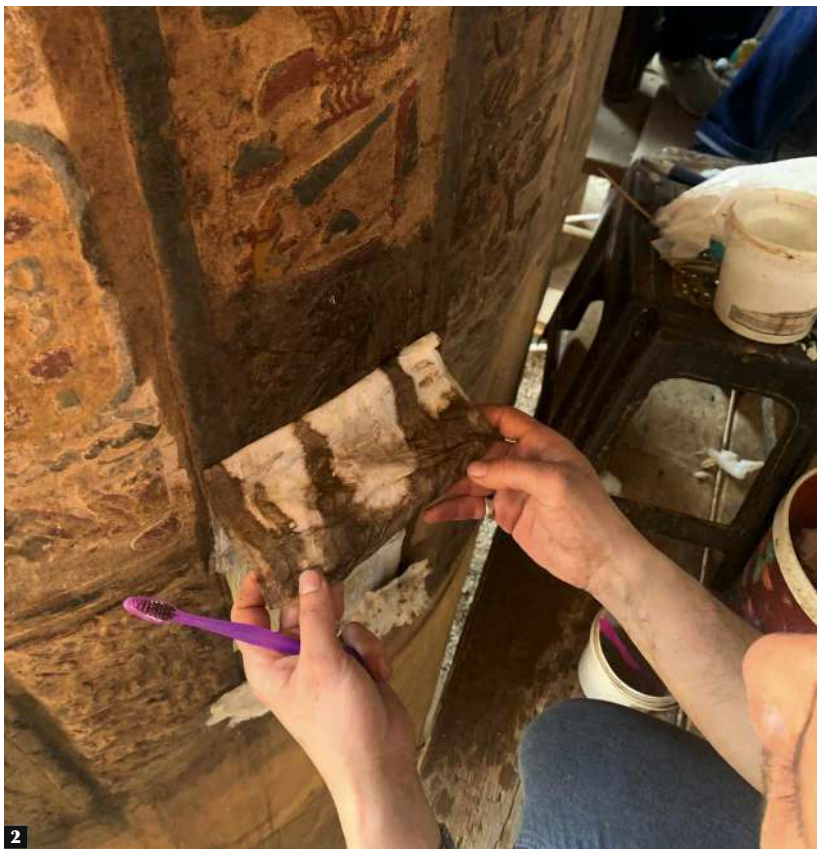
3

1. A close-up image of two of the 46 vulture figures depicted on the ceiling of the temple's central bay. The vulture-headed goddess Nekhbet is seen in the middle of the photo, with the cobra-headed goddess Wadjet below her.

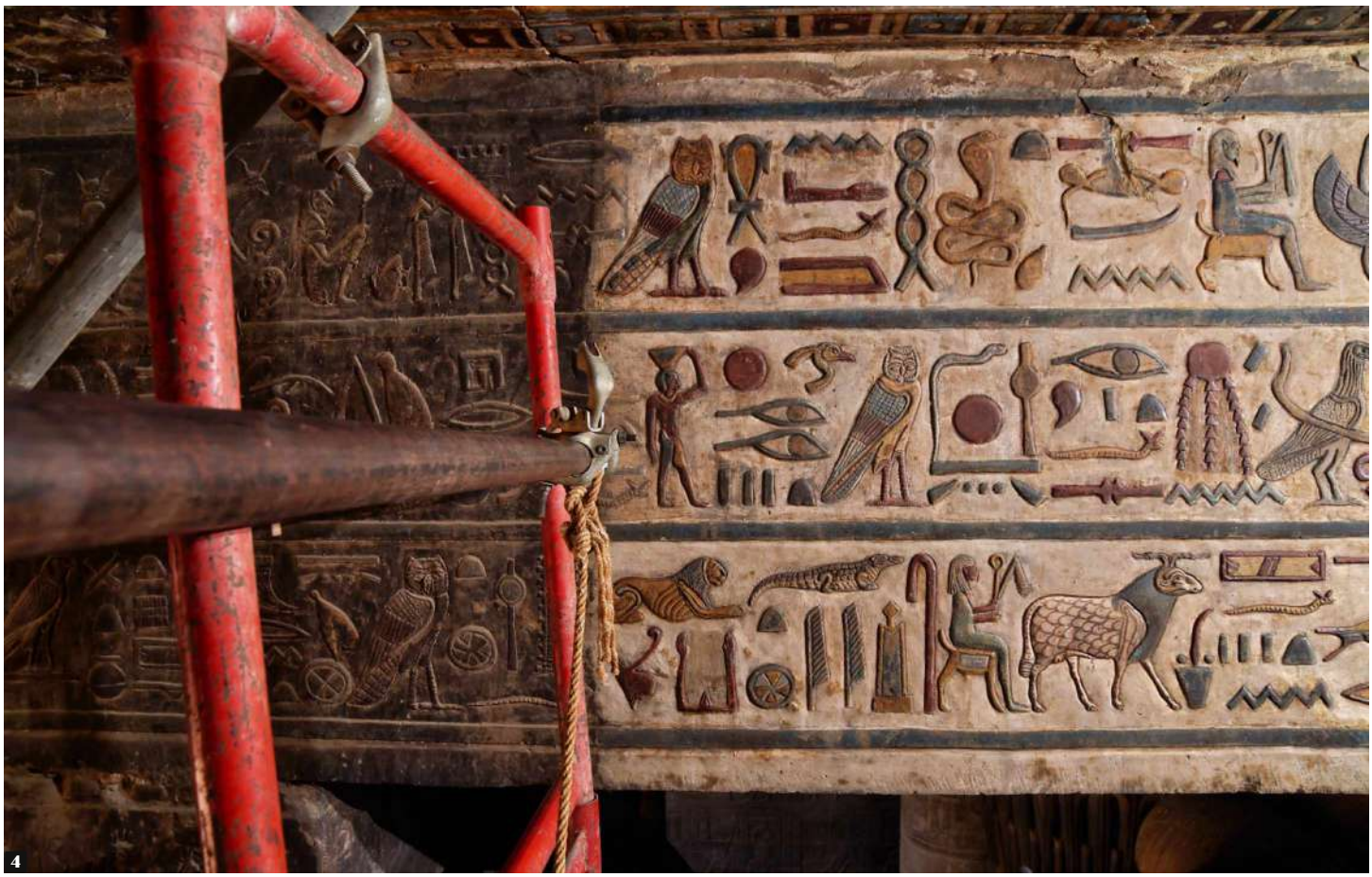
2. The restoration workers painstakingly remove 2,000 years' of dirt and soot from one of the temple's columns.

3. With the dirt and soot removed, the intricacies of the carvings are fully revealed. Note the detail in this depiction of Thoth, the ibis-headed god of science, knowledge and the Moon.

4. This work-in-progress photograph of one of the Temple of Khnum's architraves reveals the vibrant paintings and reliefs being uncovered.



2



4

AHMED AMIN/MINISTRY OF TOURISM AND ANTIQUITIES (MOTA) X5

HORIZONS

CRIME

NEW ALGORITHM PREDICTS WHEN AND WHERE A CRIME WILL HAPPEN BEFORE IT TAKES PLACE

The AI model was tested across eight cities in the US and predicts future crimes with 80 to 90 per cent accuracy, without falling foul of bias

GETTY IMAGES

YOUR ALGORITHM SUCCESSFULLY PREDICTED CRIME IN US CITIES A WEEK BEFORE THEY HAPPENED. HOW DID YOU BUILD THE ALGORITHM?

The city of Chicago and the seven other cities that we looked at have started putting out crime event logs in the public domain. In Chicago, these are actually updated daily with a week's delay.

These event logs contain information about what happened, what type of crime it was, where it happened, the latitude, longitude, and a timestamp. In Chicago, we also have information about if there were any arrests made when there were interactions with the police officers.

So we start with this event log and then digitise the city into small areas of about two blocks by two blocks – about 1,000 feet [300 metres] across. And in one of those tiles, we'll see this time series of these different events, like violent crimes, property crimes, homicides and so on. This results in tens of thousands of time series that are coevolving.

What our algorithm does is look at these coevolving time series, then figures out how they are dependent on one another and how they're constraining one another – so how they're shaping one another. That brings up a really complex model.

You can then make predictions on what's going to happen, say, a week in advance at a particular tile, plus or minus one day. In Chicago, for example, today is Wednesday. Using our algorithm, you can say that next Wednesday, on the intersection of 37th Street and Southwestern Avenue, there would be homicide.

HOW DO YOU ENVISAGE THE WAYS YOUR ALGORITHM COULD BE USED?

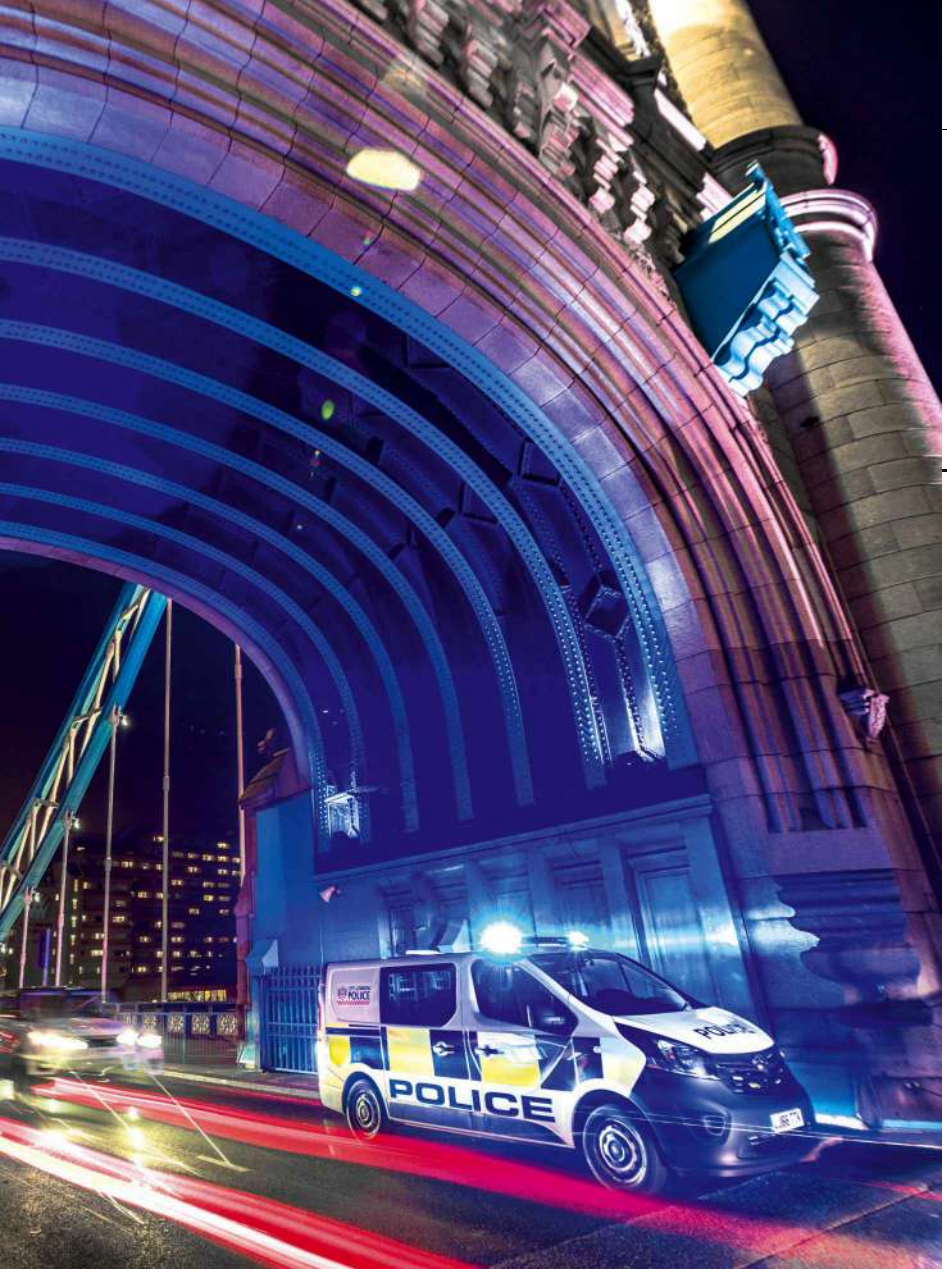
People have concerns that this will be used as a tool to put people in jail before they commit crimes. That's not going to happen, as it doesn't have any capability to do that. It just predicts an event at a particular location. It doesn't tell you who is going to commit the event or the exact dynamics or mechanics of the events. It cannot be used in the same way as in the film *Minority Report*.

In Chicago, most of the people losing their lives in violent crimes is largely due to gang violence. It is not like a Sherlock Holmes movie where some convoluted murder is happening. It is actually very actionable if you know about it a week in advance – you can intervene. This does not just involve stepping up enforcement and sending police officers there, there are other ways of intervening socially so that the odds of the crime occurring actually goes down and, ideally, it never happens.

What we would like to do is enable a kind of policy optimisation. My cohorts and I have been very vocal that we don't want this to be used as a purely predictive policy tool. We want policy optimisation to be the main use of it. We have to enable that, as just putting out a paper and having the algorithm there isn't enough. We want the mayor or administrators to use the model generated to do simulations and inform policy.

PREVIOUS ALGORITHMS OF THIS KIND HAVE BEEN HEAVILY CRITICISED FOR PRODUCING BIAS, IN TERMS OF RACIAL PROFILES, FOR EXAMPLE. HOW DO YOU ACCOUNT FOR THIS?

Approaches that have been tried before are straight-up machine



A new algorithm could help predict when and where a crime will take place

"It doesn't tell you who is going to commit the event or the exact dynamics or mechanics of the events. It cannot be used in the same way as in *Minority Report*"

learning, off-the-shelf tools where you take a giant data set, determine what the important features are, then use those features with a standard complex neural network to try to make predictions.

The issue with that approach is that as soon as you say certain features are important, you're probably going to miss things, so you will get misleading results. That happened in the Chicago Police Department [in 2014-2016]. They were putting people on the list who were likely to be perpetrators or victims of gun violence, using an equation involving characteristics like arrest histories. And that resulted in a large proportion of the black population being on the list.

We are trying to start only from the event logs. There are no humans sitting down figuring out what the features are, or what attributes are important. There's very little manual input going on, other than the event log that is coming in. We have tried to reduce bias as much as possible. That's how our model is different from other models that have come before.

A LOT OF PEOPLE ARE WORRIED ABOUT THE LACK OF TRANSPARENCY IN THE AI DECISION-MAKING PROCESS. IS THERE AN ISSUE WITH THIS?

AI systems have been used to model more and more complex systems, so it's not surprising that many of them tend to seem like a black box. Compare them to how things worked before. Back then, we just had a tiny differential equation for a system, which gave us the feeling that we understood it. If we have a giant neural network, we just can't understand what's going on. So that's an issue and there's a lot of work that's going into explaining AI.

We have a really complex model, one that you can't just look at and read off the factors from. But the way to think about it is to look at all of the event logs. There are observations from this complex social system interacting with all these socioeconomic factors, enforcement factors, demographics, economics and all of these things. All of that feeds into and shapes this social system you're modelling. You can't expect a simple kind of pattern to come out of all this data.

PROF ISHANU CHATTOPADHYAY
Ishanu leads the ZeD Lab at the University of Chicago, where he studies algorithms and data.

THE FUTURE'S BRIGHT...

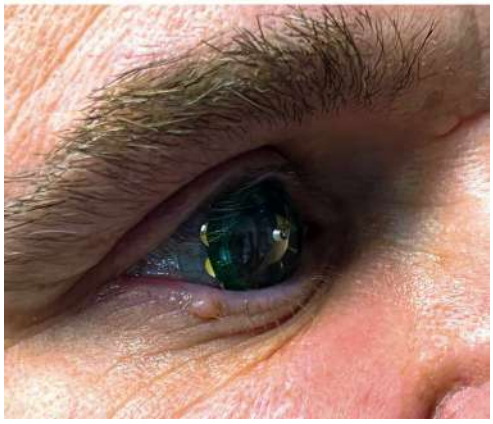
As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From smart contact lenses to venom-inspired medicines, here you'll find many reasons to feel hopeful for our future...

An implantable device could replace addictive pain-relieving drugs. It wraps around nerves to block pain signals to the brain, then dissolves naturally once its job is done. Testing in animals could be taking place in the next few years, but clinical use is a way off yet.

YEARS TO GO

25

The world's first true smart contact lens has been tested on its first human. The prototype Mojo Lens overlays a digital microLED display onto everyday vision and is powered by a tiny battery.



20

Sick of standing in front of the departures screen at the airport, searching for your flight information? Technology being trialled in Detroit Metro Airport uses facial recognition to show personalised travel information onscreen for up to 100 passengers at the same time. The screen relies on a new kind of pixel that can project light of different colours in different directions. This means it can provide separate images to people viewing the same screen from distinct angles.

ALAMY, GETTY IMAGES X2, PARALLEL REALITY, POLAR NIGHT ENERGY, MOJO LENS X2, IBM

Silicone breast implants have been used since the 1960s, but they can come with problems and health risks. Now entering human trials is a 3D-printed 'cage' in the shape of a bra cup that is inserted into the breast to stimulate the body to grow fat tissue. The cage then breaks down over time. The treatment is targeted towards those wanting reconstruction following mastectomy.

Would you like some wine with your circuit board, sir? Artificial intelligence has been given the gift of taste, as researchers have developed an AI-assisted electronic tongue capable of sensing chemical compositions. The tech has already been put on the crewless Mayflower Autonomous Ship, to monitor ocean chemistry on a journey across the Atlantic.

A heart attack treatment containing deadly spider venom has received investment, meaning the drug can move to clinical trials in the next couple of years. The drug uses a molecule found in the venom of the K'gari funnel web spider. It blocks the signals that cause the death of heart cells and could ultimately reduce the amount of permanent damage.

10

Bacteria that feed on sugar can produce a compound that is explosive enough to be used as jet fuel. If scientists can scale up production, the compound, named jawsamycin, could be used as an alternative to oil before the end of the decade.

Construction has started on a new plant in Iceland that will take carbon dioxide from the air and inject it into the ground. In 12 to 18 months, the plant should be able remove 36,000 tonnes of CO_2 each year – roughly the amount emitted by 13,300 UK households heating their homes annually.

0

A 'sand battery' in Finland is the world's first device to store power as heat within sand particles. Excess electricity from solar or wind power plants warms the sand to 500°C, which can be stored for months. The heat can later be discharged to heat water for homes, offices and a nearby swimming pool.

COMMENT

BEAUTY IS IN THE BRAIN OF THE BEHOLDER

The fascinating science of neuroaesthetics is shedding new light on the human appreciation of art

DR JULIA SHAW
(@drjuliashaw)
Julia is a psychological scientist at University College London, the author of multiple best-selling books, and the co-host of the hit podcast Bad People *on BBC Sounds.*

On a gloriously sunny day I found myself once again in the garden doing something I love – making art. I make cyanotypes, which involves using photosensitive chemicals to create images with stencils and the Sun. It's like painting with sunlight and shadows. It was the original process used for copying certain kinds of sketches, and it is because it creates strikingly blue images that we call designs or plans 'blueprints'.

My pleasure from creating the images is partly due to a sense of accomplishment and mastery, but also from the images themselves. In making my own works and also looking at the various pieces that I've collected from local art fairs over the years, I have found myself wondering how we derive pleasure from art. I went looking for the answer, and I found the science of neuroaesthetics.

Neuroaesthetics is a relatively young field of research that involves cognitive neuroscientists looking into the brain to figure out what happens when we make aesthetic assessments. Researchers use a brain imaging technique called functional magnetic resonance imaging (fMRI) to see which brain areas light up when we view paintings that we consider beautiful.

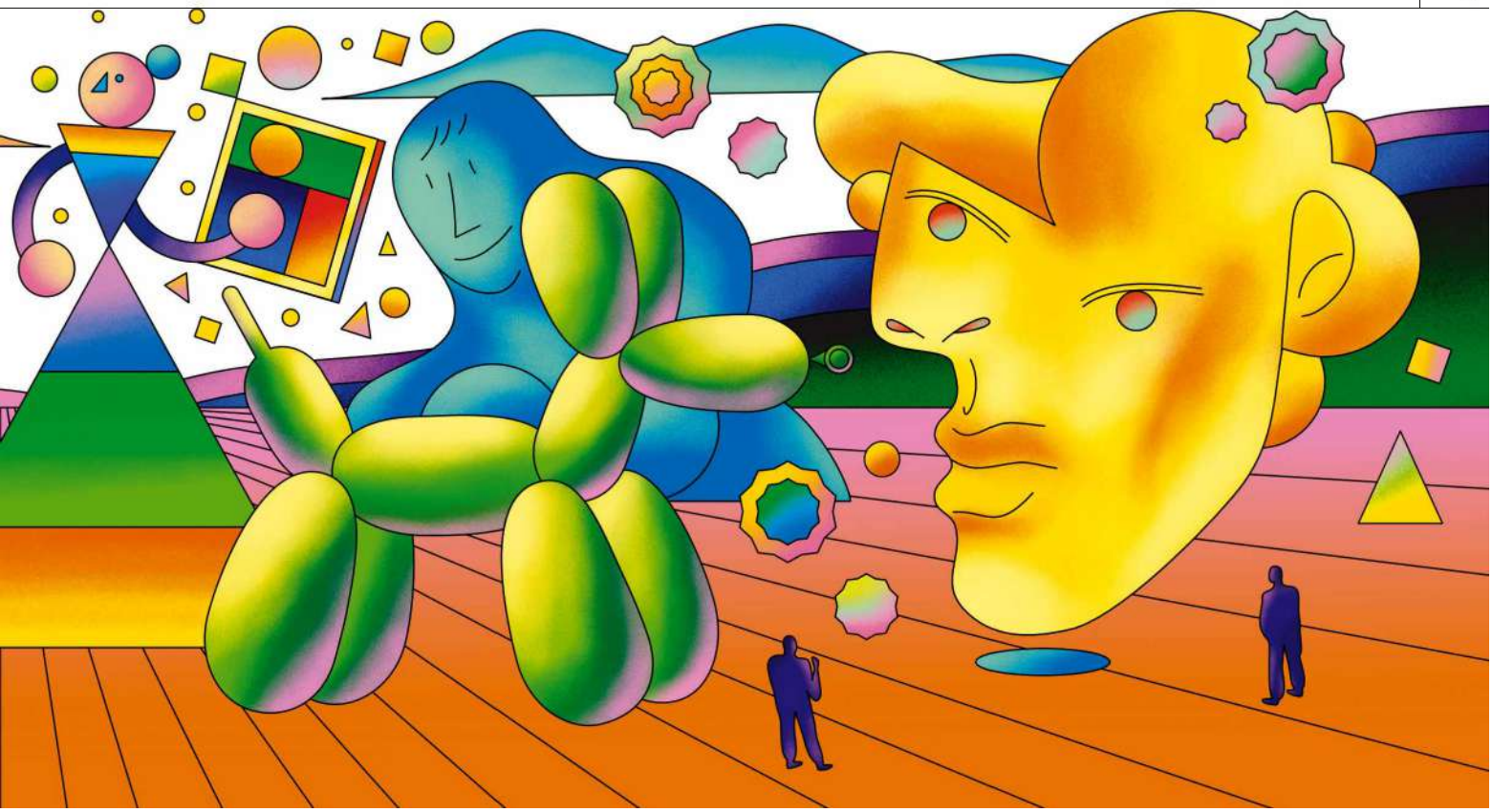
Similar research has been done to understand the neuronal fireworks that occur when we look at inspiring sculptures, pleasing interiors, attractive faces and bodies, impressive dance, and even the beauty in mathematical formulas.

But why do we find some art beautiful and other art ugly? Said differently, why do we give different aesthetic assessments to different things? According to neuroaesthetics research, it all comes down to the 'aesthetic triad'.

The first part of the aesthetic triad is sensory-motor. This involves perceiving things like colours, shapes and movements. Movement in art has an intriguing role in this. For example, if you see a painting of a movement, like of a man pulling his arm away after being bitten by a dog, your mirror neurons make you experience 'embodied resonance'. You immediately empathise with the movement, so the part of your brain that controls your own movements lights up in response.

Second is emotion-valuation. This is how a piece of art makes you feel, and whether or not

ILLUSTRATION: SCOTT BALMER



“If you use TMS on specific parts of the prefrontal cortex, you suddenly like different art”

you appreciate or enjoy that feeling. The part of the brain related to pleasure is activated in response to something we find beautiful. This system can be affected in fascinating ways, as found by research using transcranial magnetic stimulation (TMS). Rather than taking pictures of the brain like an fMRI, TMS actually changes how the brain works in a tiny, non-invasive way.

If you use TMS on specific parts of the prefrontal cortex, which is the part of your brain behind your forehead that is particularly important for decision-making, you suddenly like different kinds of art. This kind of tiny change leads to significant changes in aesthetic appreciation of faces, bodies and artworks. For example, the specific placement of TMS electrodes has made people find abstract art less beautiful. Put the electrodes elsewhere, and people appreciate art depicting humans less, probably because it interferes with how the brain perceives symmetry in faces.

The third part of the aesthetic triad is meaning-knowledge. This is to do with how we can connect with a piece of art and what meaning we can create in it. Meaning doesn’t exist inside an artwork, it can only be created inside of us. That’s why art is deeply personal and divisive, because when two people see the same artwork, our perception can create vastly different experiences of meaning. If we find meaning, then we often find pleasure.

We also get enjoyment from the knowledge of how something was made. For the cyanotypes that I create, a person viewing it will probably get far more enjoyment from the images once they know the scientific process that I use to create them. If you thought that I just printed or mass-produced them, then your enjoyment of them would go down.

Now, informed by neuroaesthetics, the next time I am in my garden creating my art I will cherish the process even more, enjoying the activation of the aesthetic triad in my brain as I admire the vivid blue images that have been made by sunlight.

BBC SOUNDS

Listen to Dr Julia Shaw on the *Bad People* podcast, available on BBC Sounds.

COMMENT

WHY WE LOVE SOME ROBOTS AND HATE OTHERS

Not all artificial intelligence is equal: just ask Clippy, Microsoft's much reviled virtual assistant

Back in 2019, MIT graduate student Daniella DiPaola and I began to frequent our local grocery store, and not to shop for food. The store had introduced a robot that we wanted to see in action. The 1.9m-tall machine roamed the aisles, scanning the floor for spills and paging the employees to clean up hazards. But what interested us most was that, despite its large googly eyes and friendly name, Marty the robot was unpopular with customers.

As robots come into shared spaces, people tend to have strong positive or negative reactions, often taking engineers by surprise. But the key to designing automated systems may be simple: recognising that people treat robots as if they're alive.

Even though robots have been building cars in factories for a while, we've seen a more recent wave of deployments in areas where they interact with people. Whether they're doing the hoovering or delivering food, robots are increasingly entering our workplaces, homes and public spaces.

"fi e biggest surge in negative comments came when the store held a birthday party for Marty the robot, complete with cake and balloons"

DR KATE DARLING
(@grok_)
Kate is a researcher at MIT, where she investigates technology and society, and studies human-robot interaction.

Part of this is due to advances in machine vision that have made it easier for robots to navigate complex infrastructure and deal with unexpected occurrences, such as MIT researchers dropping groceries in front of them to see what happens. Robot engineers have worked so diligently to make functional pieces of technology that they're often taken aback by an additional component of robot deployment: people's reactions.

In some cases, the response is overwhelmingly positive, with people adopting the robots as friends or co-workers, giving them promotions, hugs and silly hats. Over 80 per cent of Roombas, the robot vacuum made by iRobot, have names. The company was astonished to discover that some customers would send in their vacuum for repair and reject the offer of a brand-new replacement, requesting that 'Meryl Sweep' be sent back to them.

Are these people watching too many sci-fi movies? According to a few decades of research on how people interact with computers and robots, our response to these devices is about more than just pop culture. People subconsciously treat automated technology like it's alive, falling into social patterns like politeness, reciprocity and empathy. Stanford professor Clifford Nass, a pioneer in human-computer interaction, demonstrated that people will argue with computers, form bonds with them and even lie to them to protect their feelings.

While this works in some robots' favour, Marty, the robot DiPaola and I observed, got the opposite treatment. When DiPaola first noticed people complaining about it on Facebook, we wondered whether the backlash was about robots taking jobs (a legitimate concern voiced by some of the employees). But when we surveyed shoppers, they had different gripes. Many said the robot was creepy, because it watched and followed them, or got in their way. DiPaola did a sentiment analysis on Twitter, measuring positive and negative mentions of the robot. The biggest surge in negative mentions came when the store held a birthday party for Marty, complete with cake and balloons for customers.

Free cake is a strange thing for people to get upset about, but it illustrates how attempts to 'humanise' a robot can backfire. It was reminiscent of another unsuccessful attempt: Microsoft's animated Office assistant, Clippy.

Here's how Nass explained people's violent dislike for the virtual paperclip: "If you think about people's interaction with Clippy as a social relationship, how would you assess Clippy's behaviour? Abysmal, that's how. He's utterly clueless and oblivious to the appropriate ways to treat people … If you think of Clippy as a person, of course he would evoke hatred and scorn."

If we apply this human-computer interaction principle to robots, the reason people love some and hate others is because of social expectations. This means that, when done incorrectly, lifelike features can have a Clippy-effect, generating more adversity than a different tool performing the same task. Similarly, robots that harness our social expectations are extremely likeable, which is why some roboticists are teaming up with film animators to design appealing machines.

The blunders happen when robot developers focus so thoroughly on the technology that they forget the human interaction element. Integrating robots into shared spaces requires the understanding that successful engineering is only one piece of the puzzle, and that our social behaviour as humans matters at least as much as the AI.

ILLUSTRATION: ANSON CHAN

PCSPECIALIST

PORTABILITY. RECONFIGURED.

Experience the ultimate in mobile computing with a custom laptop from PCSpecialist. Our laptop configurator puts you in control, allowing you to configure a custom laptop to meet your exact requirement.

CUSTOM BUILT LAPTOPS FROM PCSPECIALIST

WWW.PCSPECIALIST.CO.UK

PCSpecialist

PCSPECIALIST

GET AN EXCLUSIVE **£15 DISCOUNT** WITH BBC SCIENCE FOCUS USING CODE: **BBF22**

ELIMINA® SERIES

- 12th Gen Intel® Core™ CPUs
- NVIDIA® GeForce GTX 1650 / RTX 3050 / 3050Ti / 3060
- 144Hz FHD Screen (72% NTSC)
- Multi-Colour Backlit Keyboard
- Windows 11 Home

Range from

£870.00*

IONICO® SERIES

- 12th Gen Intel® Core™ CPUs
- NVIDIA® GeForce RTX 30 Series
- 240Hz QHD Screen
- Magnesium Alloy Chassis
- Windows 11 Home

Range from

£1,470.00*

DEFIANCE® SERIES

- 12th Gen Intel® Core™ i7 CPUs
- NVIDIA® GeForce RTX 30 Series
- 144Hz or 240Hz FHD Screen
- Thunderbolt™ 4
- Windows 11 Home

Range from

£1,340.00*

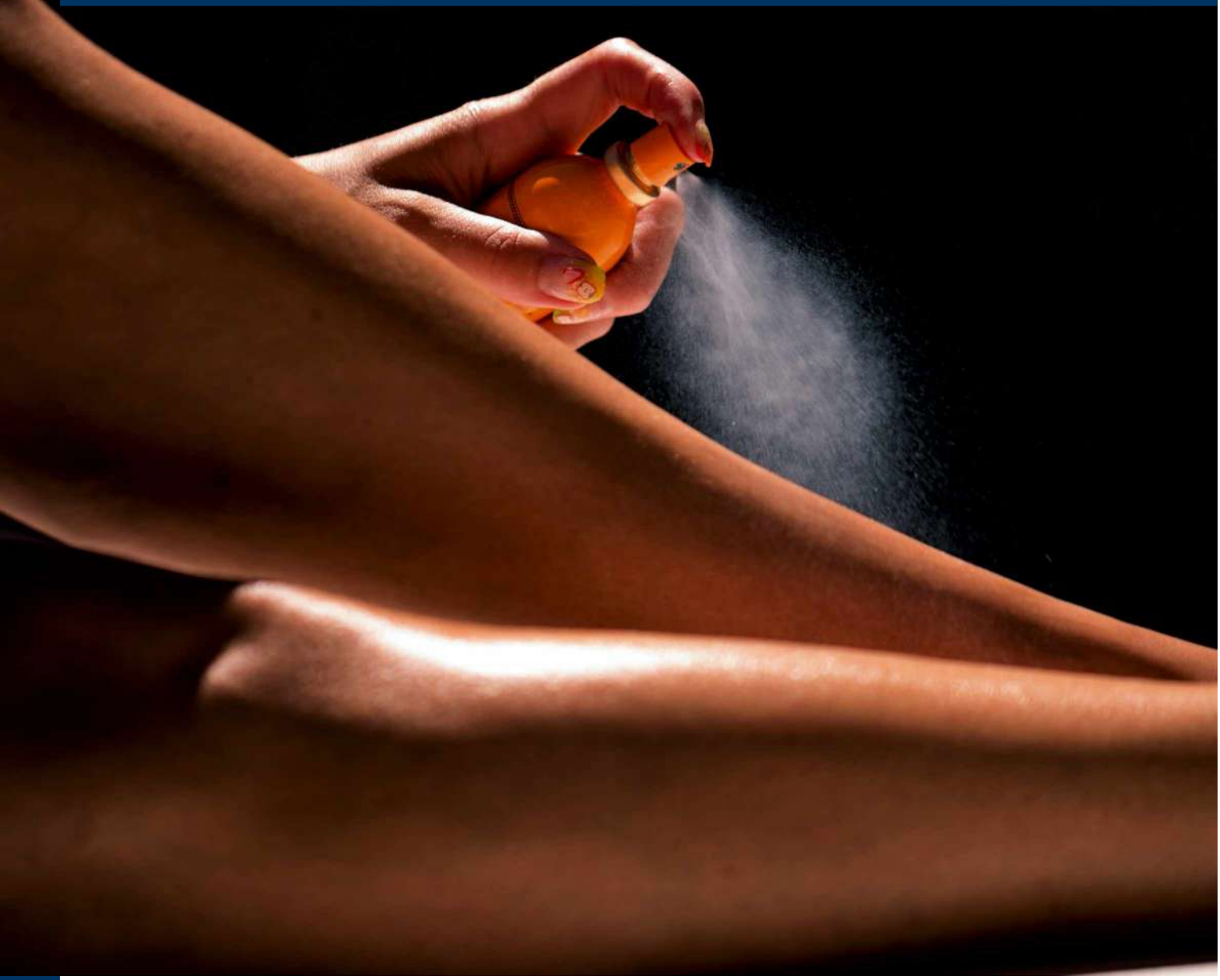
CONFIGURE YOURS AT WWW.PCSPECIALIST.CO.UK

*Prices are including VAT and are correct at time of printing, but subject to change. Images are for illustration purposes only, components may differ in aesthetics and brand.

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Suncream | Electroconvulsive therapy | Mars samples



REVIEW

SUNCREAM: HOW DO I CHOOSE THE BEST ONE?

A report from *Which?* found that several 'mineral' suncreams don't provide adequate protection

"We can easily miss hard-to-reach patches on our skin. For example, people miss, on average, 10 per cent of their face when applying sunscreen"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

Summer is here, and much of the UK is feeling the heat. As temperatures rise, more and more of us head outside for barbecues, picnics and sunbathing. However, anyone who's turned lobster-red after a few hours outdoors will know that suncream is essential, even in the UK.

But which suncream should you choose? Lotion, spray-on or roll-on? Chemical or mineral? And can you get away with a moisturiser with SPF?

WHAT SHOULD I LOOK FOR ON THE BOTTLE?

The first thing to look for is the Sun Protection Factor, or SPF. This measures how much the suncream will protect you against UVB, the higher-energy, shorter wavelengths of the Sun's UV light.

"SPFs are rated on a scale of 2 to 50+," says Prof Brian Diffey of the British Association of Dermatologists. "We recommend an SPF of 30 or more as a satisfactory form of sun protection."

In addition to SPF, make sure the suncream also displays a star rating. This is a measure of its protection against UVA, which is the lower-energy, longer-wavelength type of UV light. However, a high star rating isn't enough: this only measures how much UVA the suncream blocks in comparison to UVB, so a high star rating and low SPF is still low protection overall.

"A sunscreen with an SPF of 30 and a UVA rating of four or five stars is generally considered as a good standard of sun protection, in addition to shade and clothing," says Diffey.

IS THERE ANY DIFFERENCE BETWEEN SPRAY, LOTION, CREAM, STICK OR ROLL-ON SUNCREAMS?

"As long as the suncream offers SPF of 30 or above, it is applied in sufficient quantities and reapplied every two hours or so if the user has been in water or sweating heavily, there should not be any substantial difference in the level of protection offered by different sunscreens," explains Diffey. "Correct application of sunscreen is more important than the type of sunscreen you buy."

Therefore, you should choose whichever you find the easiest to apply. However, according to Diffey, it's generally easier to apply an even coating of suncream with a lotion.

WHAT DOES SPF MEAN?

What SPF actually represents is how many times longer it will take your skin to burn with the suncream on than without – assuming it's applied perfectly and not rubbed off on a towel or lounger, or washed off in a pool or the sea.

In theory, an SPF of 30 means it would take 30 times longer for your skin to burn. However, we rarely apply as much suncream as we should, or reapply as often as we ought to, meaning we don't get the protection advertised on the bottle.

"Most people choose to apply about half the amount of sunscreen that manufacturers use during the testing process and consequently the actual protection being delivered is about one-third to one-half of the SPF value on the bottle," Diffey explains.

"In addition, we can easily miss hard-to-reach patches on our skin. For example, people miss, on average, 10 per cent of their face when applying sunscreen."

Though it's tempting, the NHS recommends that you don't stay out in the Sun any longer ➔

Whether you opt for spray-on or lotion, make sure your sun protection has an SPF of 30 or above

GETTY IMAGES X2

while wearing suncream than you would without it.

CAN I USE AN SPF MOISTURISER INSTEAD?

Let's face it – many suncreams don't feel that nice on your skin. So, it would be great if we could swap it for a moisturiser with added SPF instead. However, Diffey recommends against it.

In a study published in 2018, researchers from the University of Liverpool used UV photography to see whether SPF moisturisers could provide the same level of protection as suncreams. They asked participants to apply suncream or SPF moisturiser, and then shone a UV lamp on them. The researchers then took photos of the participants using a camera that had been modified to capture only UV light. In these photos, the participants' skin looked darker where the suncream was absorbing UV light: the darker it appeared, the better the protection.

In the photos with the SPF moisturiser, the participants' skin was less darkened than with traditional suncream. This means that the SPF moisturiser provided significantly less protection, though it was better than nothing. (These photos also revealed that many people miss the area around their eyes when applying suncream.)

"Also, moisturisers will wash off the skin more easily than sunscreens designed for recreational use," says Diffey.

WHAT'S THE DIFFERENCE BETWEEN CHEMICAL AND MINERAL SUNCREAMS?

The names 'chemical' and 'mineral' refer to the way that the suncreams block UV light – and Diffey says they should technically be referred to as 'organic' and 'inorganic' suncreams, respectively.

"Organic sunscreens work by absorbing UV rays and converting the energy into harmless heat that we can't feel, whereas inorganic sunscreens will not only absorb UV rays but also scatter some of them away from the skin," he explains.

Chemical suncreams often contain ingredients such as oxybenzone, whereas mineral suncreams often contain titanium dioxide and zinc oxide.

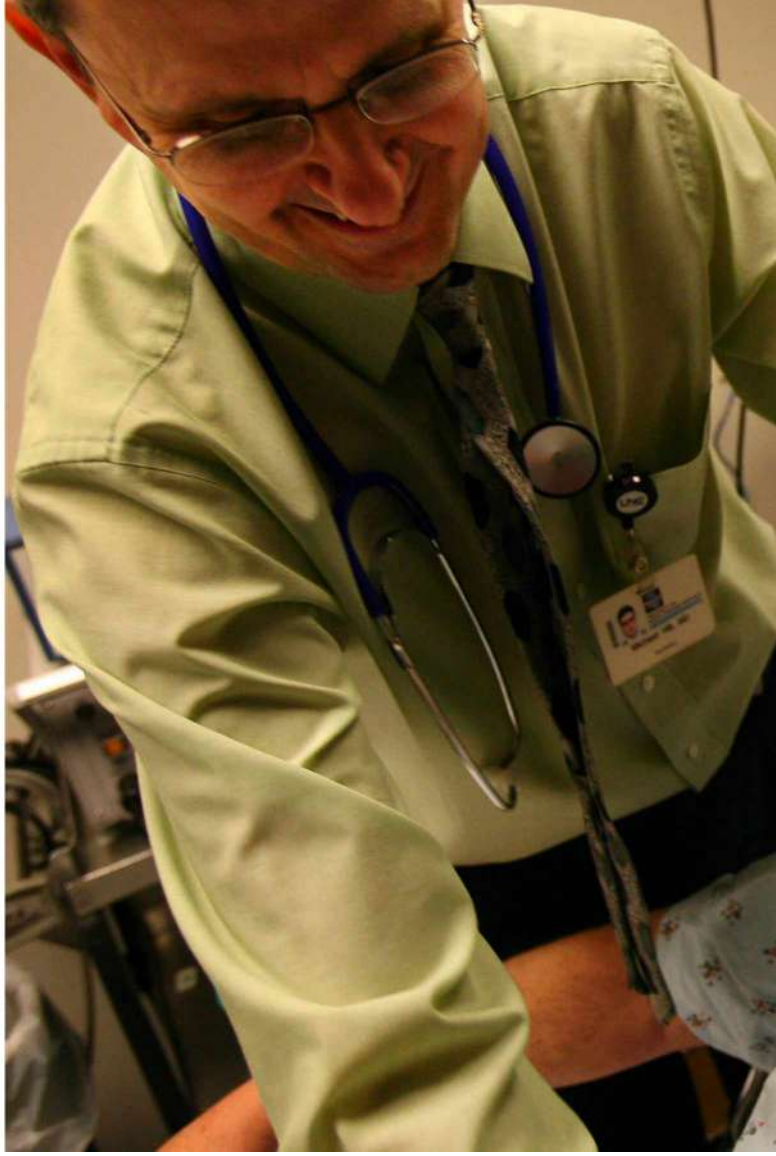
"Organic sunscreens tend to be the most popular amongst consumers as they spread more easily across the skin," says Diffey. "Inorganic sunscreens often leave the skin with a whitish appearance, which can be more pronounced on darker skin types."

If you're going to choose an inorganic suncream, beware: a report by *Which?* found several brands of expensive mineral sunscreen that didn't provide the advertised SPF.

Regardless of which you choose, make sure you also cover up with clothes, stay out of the sunshine in the hottest part of the day, and reapply regularly.

by **SARA RIGBY**

Sara is the online sta writer at BBC Science Focus. *She has an MPhys in mathematical physics.*



ANALYSIS

ELECTROCONVULSIVE THERAPY: DOES THIS TREATMENT REALLY WORK?

Recent reports claim that the controversial treatment can cause brain damage and memory loss

The use of electroconvulsive therapy (ECT) as a treatment for severe mental health problems, including intractable depression, has come under renewed scrutiny. Sometimes referred to disparagingly as 'shock therapy', ECT involves passing an electric current through the

GETTY IMAGES

ABOVE A patient is prepared for ECT to treat severe depression

brain to deliberately induce a brief seizure. The fresh concerns follow a series of recent newspaper reports based on an NHS audit that showed the continued widespread use of the practice in England.

The Independent ran a story that said, "Thousands of women given 'dangerous' electric shocks as mental health treatment in England", which also featured an interview with a woman who'd received ECT and said it had badly affected her memory. *The Observer* ran the headline, "Brain damage claim leads to new row over electroshock therapy".

The NHS England data that fuelled these stories was actually published in 2021 by a research group led by the academic and clinical psychologist Prof John Read – a long-time critic of ECT who believes the practice should be banned. The data showed that 1,964 patients received ECT in England in 2019 and that 67 per cent were women. Read doubts the effectiveness of ECT and says it causes long-lasting or permanent brain damage and memory loss.

First developed in the 1930s, ECT was sometimes misused in its early years and will be forever associated with the character Randle McMurphy, played by Jack Nicholson in the 1975 film *One Flew Over The Cuckoo's Nest*. McMurphy, a mental health patient, is brutalised by medical staff, including being given ECT against his will.

"Today, ECT is only recommended in extreme cases where other treatments have failed"

So, what is the truth about this treatment and the claims that it causes memory problems and brain damage? It's important to note that ECT has changed from its early years, when it was used without muscle relaxant or anaesthesia. Both of these are part of the basic protocol today. Also, bear in mind that ECT is only recommended in extreme cases where other treatments have failed and/or a patient's problems are so severe as to be life-threatening.

That said, the concerns about ECT are not unfounded. There is published data indicating adverse effects on memory following ECT. Meanwhile, the National Institute for Health and Care Excellence (NICE) – the independent body that advises the UK government – states that many patients report memory loss after ECT and, for some, the effects of this impairment outweigh any benefits.

However, the notion that ECT causes brain damage is harder to support. In an in-depth essay for *Aeon* magazine, Read cited a review from *The Lancet* from 1946 that speculated about signs of brain damage seen in the autopsies of patients who'd had ECT. But the author of that review, Bernard Alpers, was cautious in his interpretations (many of the patients had complex health problems that could have caused the damage) and he wrote that "clinical experience has long since taught that electrical shock treatment is safe". Turning to more recent evidence, Read cited a 2012 study that found reduced functional connectivity in the front of patients' brains after ECT, yet many experts would dispute that this change in functional activity is a sign of brain damage (the study authors themselves did not use this language) – especially as it correlated with improvements in symptoms.

Other reviews not mentioned by Read are more reassuring, such as a 2006 paper in *The American Journal Of Psychiatry* that concluded "there is no ➤

Today, patients are given muscle relaxants and anaesthesia prior to receiving ECT

credible evidence that ECT causes structural brain damage". A review in the *Indian Journal Of Psychiatry* in 2020 similarly stated that "there is a lack of evidence at present to suggest that ECT causes brain damage".

In its guidance, NICE states: "The six reviewed studies that used brain-scanning techniques did not provide any evidence that ECT causes brain damage".

It's also worth noting the recent animal research carried out at the University of Heidelberg, Germany, suggests that ECT can actually stimulate neurogenesis, which is the growth of new neurons. Other research points to increased volume in various brain areas after ECT. Taken together, researchers believe the therapeutic benefits of ECT could be related to various brain processes including increased neuroplasticity, which can be compromised in depression.

Prof Wendy Burn is Chair of the Royal College of Psychiatrists Public Engagement Board and she previously worked on a leaflet about ECT produced for the public.

"ECT remains an important treatment for people with severe depression who have not responded to other treatments," she says. "This is recognised by NICE, which has recently reviewed its guideline for the treatment of depression and continues to recommend it. A higher number of women than men receive ECT because they are more likely to experience depression and more likely to ask for help."

by **DR CHRISTIAN JARRETT**

Christian is a psychologist and neuroscientist. His latest book is Be Who You Want: Unlocking The Science of Personality Change *(£14.99, Robinson).*

COMMENT

MARS: COULD MARTIAN ROCK SAMPLES CONTAMINATE OUR PLANET WITH MICROBES?

NASA and ESA plan to bring back samples from the Red Planet within the next two decades

NASA and the European Space Agency (ESA) are teaming up to return a sample of Martian material to Earth in the 2030s, but that has provoked fears in some quarters that we could be bringing back more than just rock and air. Could we inadvertently contaminate Earth's biosphere with Martian microbes?

The scientific desire for a Mars sample return is clear. The Moon rocks returned to the Earth by the Apollo astronauts over half a century ago are still studied to this day and are a treasure trove of invaluable information about the Moon's composition, history and formation.

And while we've had a permanent presence on the Martian surface for 25 years now, scientists are keen to study pristine pieces of Mars in the lab. After all, our laboratories on Earth are far more advanced than anything we can squeeze into a rover.

The plan is to dispatch two courier spacecraft to Mars in the late 2020s to collect samples of rocks, soil and atmosphere gathered up by the Perseverance rover currently trawling the Martian surface. A spacecraft would land nearby and transfer the samples over from Perseverance. It would then launch into Mars orbit to rendezvous with the second spacecraft, which would then transport the samples back to Earth sometime in the early 2030s.

But what are the chances they'll bring back more than they bargained for?

"The question of whether samples from Mars could present a hazard to Earth's biosphere has been studied by several different panels of scientific experts over the past several decades," NASA says. "The reports from these panels have found an extremely low likelihood that samples collected from areas on Mars, like those being explored by Perseverance, could possibly contain a biological hazard to our biosphere."

The agency points to the fact that Earth is regularly hit by meteorites from Mars and there's no evidence of any subsequent contamination.

According to an ESA report, the probability that a single unsterilised particle bigger than 0.0002 millimetres across will be released into Earth's environment by a sample return is less than one in a million. That's *any* particle from Mars – the chances

SCIENCE PHOTO LIBRARY, NASA/JPL

"Mars samples would be treated with the highest level of care once having landed, as if they could be hazardous biological materials"

of that particle being biological are significantly lower as we don't even know if there is any life on Mars.

The chances are so low because NASA and ESA are putting in place a series of stringent steps to reduce the risk as much as possible. For starters, they'll only collect material from the first few centimetres of the Martian surface. This surface material is extremely dry and bombarded by intense radiation from the Sun. If there is microbial life on Mars, it is unlikely to reside there as it would be quickly sterilised.

Still, a multi-layered containment system is being put in place just in case.

ABOVE Concept of the sample return mission, which would see various spacecra working together to obtain Martian rocks and bring them back to Earth

"The planned approach would provide higher levels of isolation than anything achieved previously in space flight, including for the samples of lunar rocks, comet dust, asteroids, and the solar wind successfully captured and returned to Earth by earlier NASA and international missions," NASA says.

Once the sample reaches Mars orbit, it will enter the Capture, Containment and Return System (CCRS). It will be sealed inside the first of two containment vessels, while being heated to sterilise any stray Martian dust. Only then will it enter a so-called 'clean chamber', which is then sealed for its trip back to Earth.

Then it's all about ensuring the whole thing remains sealed until scientists can access the samples in carefully controlled labs here on Earth. The CCRS is fitted with a shield to protect it from micrometeorites, which could puncture the seal on the return trip. Even the route home has been carefully considered.

"The trajectory of the return orbiter would be pointed away from Earth until a few days before the planned landing, allowing a final decision to be made about proceeding with Earth entry using all available information collected during the entire mission," NASA says.

Rigorous pre-flight tests will ensure the probe can withstand the searing temperatures and crippling g-forces of atmospheric re-entry. Then it's time for researchers to don their hazmat suits.

"Out of an abundance of caution, the entry system and its samples would be treated with the highest level of care once having landed, as if they could be hazardous biological materials," NASA says.

It will quickly be encased in yet more containing layers for transport to a dedicated receiving facility. Only then will scientists be able to assess their hard-won treasure.

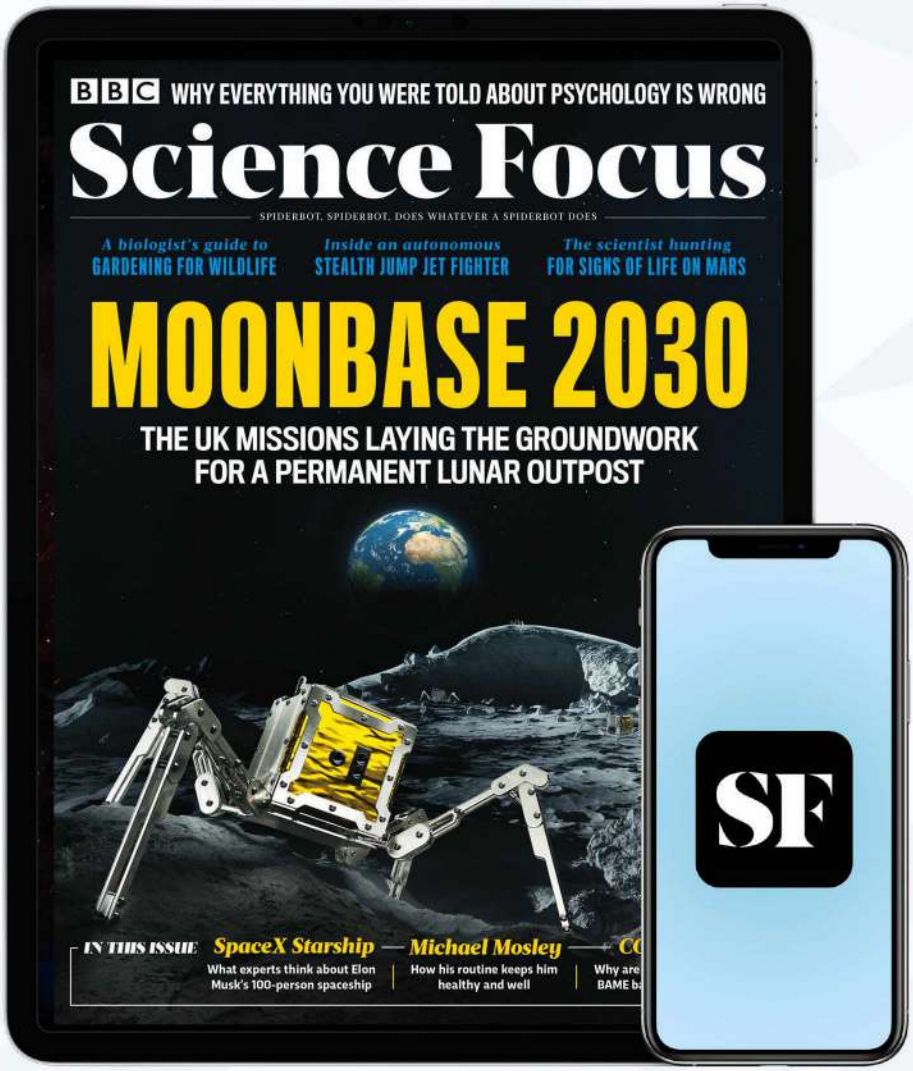
So, while the risk to Earth's biosphere is not zero, NASA and ESA seem confident that they've put the necessary steps in place to make contamination as close to impossible as it can be. **SF**

by COLIN STUART *(@skyponderer)*
Colin is an astronomy writer and speaker.

BBC

Science Focus

MAGAZINE


BBC WHY EVERYTHING YOU WERE TOLD ABOUT PSYCHOLOGY IS WRONG
Science Focus
SPIDERBOT, SPIDERBOT, DOES WHATEVER A SPIDERBOT DOES
A biologist's guide to GARDENING FOR WILDLIFE
Inside an autonomous STEALTH JUMP JET FIGHTER
The scientist hunting FOR SIGNS OF LIFE ON MARS
MOONBASE 2030
THE UK MISSIONS LAYING THE GROUNDWORK FOR A PERMANENT LUNAR OUTPOST
IN THIS ISSUE
SpaceX Starship
What experts think about Elon Musk's 100-person spaceship
Michael Mosley
How his routine keeps him healthy and well
SF

All the latest ideas, discoveries & big questions answered...

Install the official *BBC Science Focus Magazine* App today and get instant access to the current issue when you subscribe. With each new issue, you'll get the lowdown on the latest discoveries and big breakthroughs affecting our future.

SEARCH *BBC SCIENCE FOCUS MAGAZINE* IN THE APP STORE

Download on the App Store

GET IT ON Google Play

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

FIRST TEST

JACK OF ALL TRADES...

Can DJI's newest do-it-all drone really do it all? p46

FIVE OF THE BEST

ENERGY-SAVING GADGETS

Smart devices to cut the cost of heating and lighting your home p48

NEW TECH

IDEAS WE LIKE

The kit that's got us smashing open our piggy banks this month p50

ft NuraTrue Pro earbuds: aiming for audio excellence without the wires (see p51)

94%

DJI DRONES

The share of the consumer drone market made up by DJI in 2021

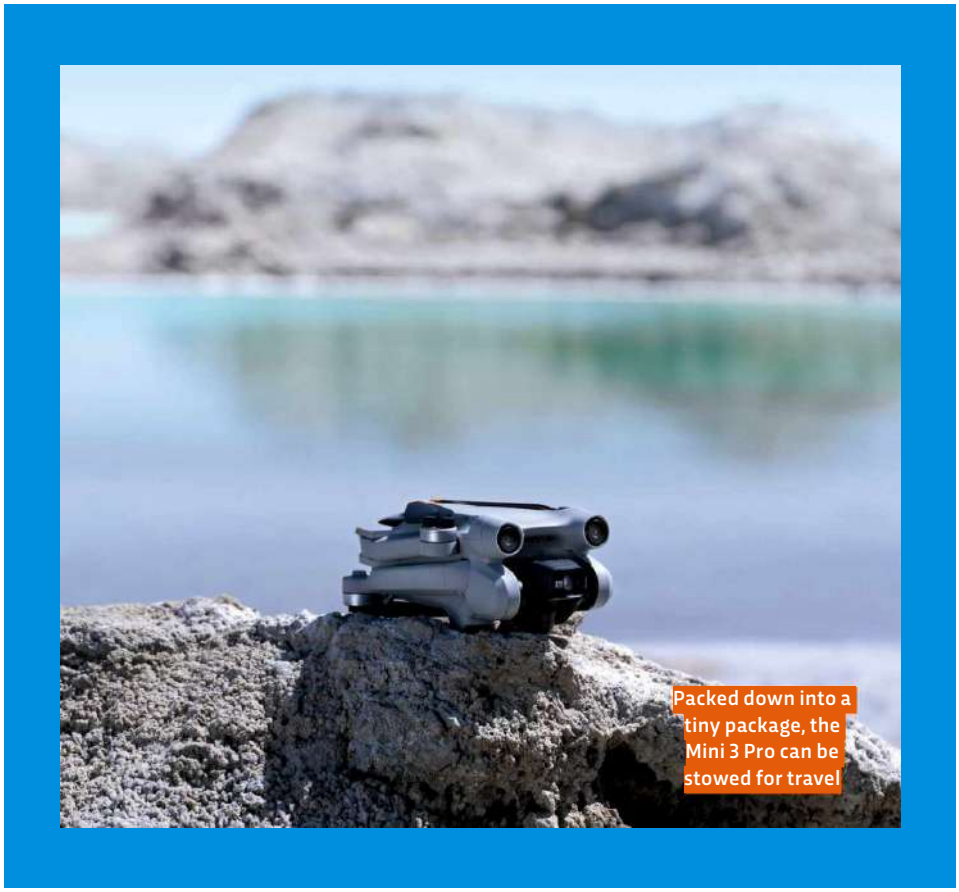
£55 per year

The amount the average household could save by switching to LED bulbs

REVIEW

DJI Mini 3 Pro: Jack-of-all-trades, master of... most

Alex Hughes tries out DJI's newest do-it-all drone and finds it's light, easy-to-use, full of features and... hard to criticise


Packed down into a tiny package, the Mini 3 Pro can be stowed for travel

DJI's new Mini 3 Pro drone can fly at speeds of 56km/h (35mph), reach heights of up to 500m (1,640 feet) and distances of around 24km (15 miles). These are some daunting specs for someone like me who has never touched a drone before, and yet DJI promises the Mini 3 Pro delivers an experience that even a complete beginner can enjoy.

In many ways, DJI has tried to develop a Jack-of-all-trades drone – one that's simple enough for a novice pilot to quickly learn to fly, but that also packs in a Pandora's box of advanced features for more experienced users.

But in a Venn diagram with drone newbies on one side and expert aerial photographers on the other, does the DJI Mini 3 Pro sit snugly in the central sweet spot, or does its attempt to please everyone end up leaving nobody fully satisfied?

SETTING UP AND LEARNING THE CONTROLS

Setting up is surprisingly simple. There's just the drone, batteries and a charger. Depending on which version is purchased, there's also a controller with a built-in screen, or one with a mount for a smartphone. I tested the model with the built-in screen.

Folded up, the drone is about 145 x 90 x 62mm, so it can sit comfortably on your hand. And even with the propellers unfolded, it doesn't get much bigger.

Another big selling point is the drone's weight, or rather lack of it, coming in at less than 249g (about the weight of a large hamster).

The controller offers a lot of information, and its display shows you what the drone's camera sees. It also gives you the ability to play with different settings, like highlighting a target to track, or switching between filming modes.

On the left-hand side of the screen, a map shows you the drone's location, and on the right-hand side are all of the video and photography controls. These offer different aperture and zoom adjustments, as well as portrait and landscape modes.

THE FLYING EXPERIENCE

Getting the drone up into the air and landing it is as simple as pressing a button. Pushing the button lifts the drone to waist-height and you take control from there. The same button is used to land it too.

The left analogue stick controls the drone's height and rotation, making it go up, down and spin. The right analogue stick makes it go forward, back, left and right. Simple on their own, but it's a much bigger challenge to make them work together!

Those who don't have enough flying experience to pull off backflips and sharp turns are saved by the obstacle avoidance sensors in the drone. Get too close to an object and the Mini 3 Pro will autocorrect to save itself from a painful, expensive crash. That's a relief, as the drone has a price tag that starts at £709.

DJI provides further automation in the form of manoeuvres known as 'Quickshots'. Quickshots can shoot the drone up like a rocket while focusing on a target, or make it circle someone it's filming, or get it to

The tech crammed into the Mini 3 Pro helps novice flyers keep it safely in the air

pull backwards from an object or person, along with other clever tricks.

There is also a mode called 'FocusTrack', which keeps the camera trained on a particular target that you select while the drone flies around and follows it. This is perfect for following someone as they run, drive, cycle or generally move at a pace that might be hard for inexperienced flyers to keep up with.

For more accomplished drone pilots, there are advanced settings. DJI offers three modes with the Mini 3 Pro: cine mode (slow), normal, and sport (fast). While cine mode allows you to slowly track what you're filming, and will be best for most situations, those with rather more flying experience (and a lack of fear) can crank it up to sport mode.

Keep in mind that in sport mode, the drone disables obstacle avoidance, so it requires precise flying skills. There's also a manual mode for imaging that gives you options to control shutter speed, ISO and white balance – all useful features for more advanced filmmakers.

BECOMING AN AERIAL PHOTOGRAPHER

Despite its smaller and more portable design compared to DJI's other drones, the Mini 3 Pro still produces excellent images and videos. When recording video, it can achieve 4K footage at 30 frames per second (fps). However, it can go all the way up to 120fps, with a reduction in the quality as the frame rate increases.

When it comes to still images, the Mini 3 Pro features a 12.1-megapixel (MP) sensor, able to take 48MP photos. In most scenarios, especially large scenic shots, the image quality is really impressive. Whether you're shooting stills or video, the camera captures the real-world well, accurately displaying colours and the level of light. On sunny days, it can struggle with minor details, along with overexposure.

RATING: ★★★★★

PROS:
- Lightweight
- Easy-to-use
- Takes excellent photos and videos
- Full of advanced and clever features

CONS:
- Quite expensive
- Very fragile

VERDICT

For anyone in the market for a new drone, the DJI Mini 3 Pro is hard to ignore. Yes, there are cheaper alternatives out there, as well as sturdier, feature-rich drones. But the Mini 3 Pro sits perfectly in the middle of those options.

For beginners, this device offers a simple operating system with which to gain drone experience. When you're ready for a challenge, there is a treasure trove of more sophisticated settings to explore.

But there is plenty to satisfy those with more advanced drone knowledge. The lightweight nature of the Mini 3 Pro is one of its big selling points. Plus, DJI has crammed the device full of professional filming features, for those who want to get creative with their drone photography.

3 ALTERNATIVE DRONES

FOR DAREDEVIL PILOTS... DJI FPV

£1,249, dji.com

While the DJI Mini 3 Pro is lightweight and speedy, it isn't the fastest or most nimble drone out there. First person view (FPV) drones use headsets so the pilot can see what the drone sees. With the DJI FPV (below), you can perform loops, dives, sharp turns and generally move about in a way you can't with other drones. While flying the thing takes a higher level of skill, the result is impressive, with the drone capable of darting around obstacles.

FOR PILOTS ON A BUDGET... RYZE TELLO

£99, ryzerobotics.com

If you just want an affordable starter drone, the Ryze Tello is a great choice. It only costs £99 and weighs just 80g. It can only fly for 13 minutes, and is limited to 720p video quality. It also lacks the same level of features and protections that DJI's more premium drones get.

FOR PILOTS WITH CASH TO SPLASH... DJI MAVIC 3

£1,729, dji.com

If you want all the functionality and features you can get, consider the DJI Mavic 3. It's DJI's most powerful drone and has a dual-camera system that can record in 5.1K, or up to 200fps at a lower quality, and can fly for as long as 46 minutes. It's easily the best drone for filmmakers, but it's pricey and heavy (895g).

The essentials... energy-saving tools

With food, fuel and energy prices on the rise, we're all feeling the pinch. These gadgets could help you save money on your bills

Nest Learning Thermostat

£219, store.google.com

Co-created by Tony Fadell, whose CV includes the iPod and iPhone, the Nest Learning Thermostat claims to have saved almost 40 billion kWh of energy worldwide since it launched, and offers a 10 per cent to 12 per cent saving on heating and cooling per household. The intelligent thermostat spends a week learning your heating and cooling preferences, then creates a schedule and makes small adjustments to use less energy while keeping you comfortable.

The Nest can be adjusted manually via its weighty, stainless-steel dial, but also connects to your smartphone for remote control. By knowing the location of your phone, it can turn the heating down when you go out and turn it back up again when you return.

Nest claims the thermostat will pay for itself in less than two years, based on the energy it saves.

Tado° Smart Radiator Thermostat V3+

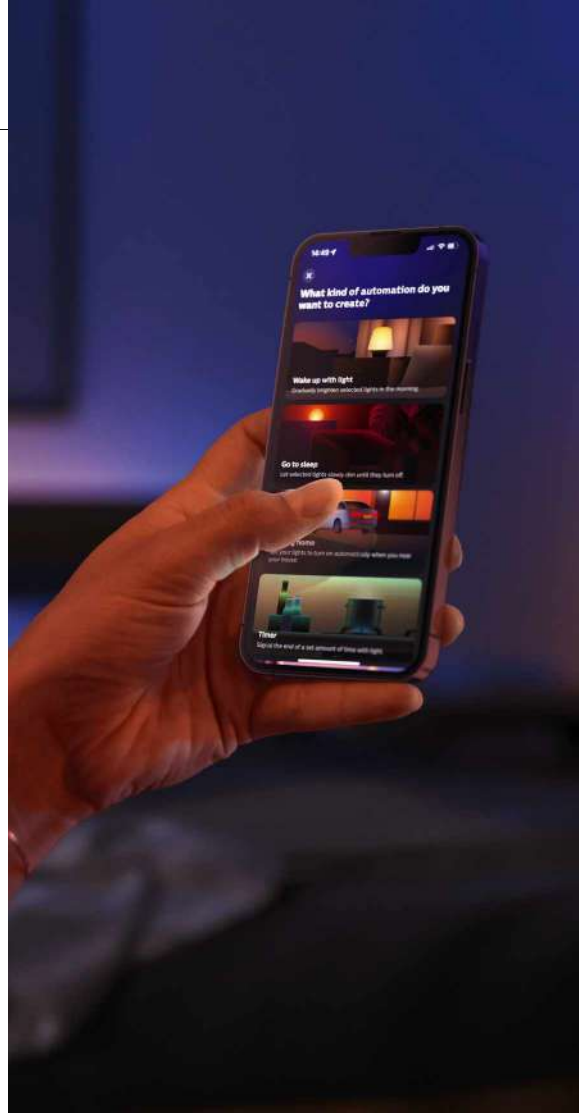
£119, tado.com

Controlling your heating centrally with a smart thermostat is a good start, but Tado°'s Smart Radiator Controller takes things a step further. Powered by two AA batteries, it replaces the manual temperature controller on your radiator.

Once fitted, each smart controller connects to your Wi-Fi network so you can operate your radiators via an app, or a smart home system such as Google Home, Amazon Alexa or Apple HomeKit. Not only does this make it easier to reduce your home's energy demands by turning down the heat in rooms that aren't being occupied, but by knowing the location of your smartphone, the Tado° Smart Radiator Thermostat can automatically raise the temperature as you make your way home after being out. It's also easy to set schedules for each room in the app, so only those you use regularly are heated.

Add Tado°'s thermostat to your smart home system and your home can be heated or cooled according to local weather forecasts, and the app will alert you if it thinks you've accidentally left a window open, or if a room isn't heating correctly.

Based on a study into energy-saving potential within the home, Tado° claims to reduce your energy consumption by up to 31 per cent.



Philips Hue Smart Lights

From £69.99, philips-hue.com

LED lights are a great way to lower your home energy use, since they're around 90 per cent more efficient than traditional bulbs. While Philips Hue smart lights consume slightly more energy than non-smart LEDs, owing to their wireless connectivity, they have some nifty features to help restore that balance.

The Hue system can be set to turn off some (or all) of your lights when you go out, lower bulb brightness, and even light up in your choice of 16 million colours. Via the Hue app, bulbs can be divided into groups and given daily or weekly schedules, and motion sensors can be used to have a bathroom light come on at night, for example.

Lastly, a feature called 'presence mimicking' turns your lights on and off to make it look like an empty home is occupied – a cheaper and more energy-efficient alternative to leaving a couple of lamps on all day.

WeeKett smart kettle

£89.99, weekett.com

Did you know that many hot drinks are best brewed with water that isn't quite boiling? Green tea should be 80°C, for example, and only black tea should get the full 100°C treatment. The WeeKett helps save energy by heating water to exactly the right temperature, with buttons for 70°C, 80°C, 90°C and 100°C.

With Wi-Fi connectivity and integration with the Smart Life app, the kettle can be set to any temperature as low as 40°C. There's also the option to maintain a certain temperature for up to an hour, and a baby bottle mode heats to 100°C, then keeps the temperature at a steady 70°C for an hour.

The app also displays the current water temperature, so in some cases you can get away with making a second drink without needlessly boiling the still-hot water again. There's also voice control via Amazon Alexa and Google Assistant, so you can ask the smart speaker in your bedroom to fire up the kettle, knowing it'll be ready when you get to the kitchen.

TP-Link Kasa Smart Wi-Fi Plug

£44, tp-link.com

Smart plugs, like this one from TP-Link's Kasa range, can make almost any household appliance smart. Fitting between an appliance's plug and the wall socket, it has Wi-Fi for connecting to the internet and can be controlled from smartphone apps, home-automation systems such as Apple HomeKit, and voice assistants like Amazon Alexa.

The Kasa is quick and easy to set up, with schedules that can be personalised for every day of the week. The plug can be controlled when you're away from home – handy if you want to check if your straighteners are off.

Although smart plugs consume energy to function, the wireless tech they use is incredibly efficient. Zigbee and Z-Wave, a pair of smart home wireless standards, account for around half a watt.

As for saving you energy, this is achieved by setting schedules that shut down your devices when they aren't needed, instead of you leaving them in standby mode.

Research from the National Renewable Energy Laboratory showed that using smart plugs could save up to 4.58 per cent of energy usage a year – a small, but noticeable difference.

Ideas we like...

Our pick of the month's smartest tech

...smart boots that keep your feet safe

Hiking boots, for the most part, all roughly follow the same rugged formula, leaving innovation to one side in favour of tried-and-tested durable construction. However, these new boots are looking to spice things up, or at least add as much spice as you can when it comes to hiking! Terrein hiking boots make it nearly impossible to roll your ankles, saving you from the sprains or injuries you can get from walking on a bumpy path. They do this with pistons that stabilise your foot when you start to slip, preventing a twist or tear in the joint.

Terrein Boots
£170, terrein-footwear.com

↑ ...super-powered solar panels

Whether you're living off-grid or preparing for an apocalypse, a good solar energy setup is a great investment. Even more so if it combines portability with storage capacity, This is why Jackery has created the 2000 Pro. It comes with six solar panels and a power station and is capable of charging 2,160Wh in just 2.5 hours (enough to power a projector for 15 hours, or an electric grill for an hour).

Jackery 2000 Pro
$6,199, jackery.com

↑ ...wireless earbuds for audiophiles

Bluetooth is great for headphones, saving you from getting tangled up in wires. But as any audiophile knows, Bluetooth also stops you getting the full quality of your music. With its new NuraTrue Pro earbuds, Nura is looking to get around this by producing a lossless pair of earbuds. While they're not cheap, this will be the first pair of Bluetooth earbuds able to receive CD-quality audio.

NuraTrue Pro
£299, nurasound.com

↑ ...holograms in the home

Even the most jaded tech critics can't help but get excited when it comes to holograms. While most successful attempts have been at concerts, Proto Hologram hopes to bring holograms into your home for video calls, medical scans and all sorts of other 3D experiences. It's great in theory, but that's all it could end up being, if Proto can't nail the design.

Proto Hologram
£TBC, protohologram.com

↑ ...a speaker like no other

If you're bored of the same tired speaker design, this new model from Transparent could be just what you're looking for. Modelled on the human ear, this made-to-order speaker looks closer to something you'd find in an art gallery. It has Bluetooth and a modular design that allows you to replace or upgrade parts of the speaker.

Acoustic Sculpture
£2,350, transpa.rent

IDEAS WE DON'T LIKE...

...AN NFT MEMBERS CLUB

Just when we thought we'd seen all possible types of NFTs, comes a new one: NFT members clubs. Sho Group is a members-only club, restaurant and events scheme. It offers three levels of membership, Earth, Water and Fire, all in the form of NFTs starting at $7,500 and working up to $300,000. These include access to an exclusive restaurant, lounges, online 'pop-ups', educational events and a trip to Japan.

Sho Group NFT-based membership
From $7,500, shogroup.com

...A SMARTWATCH THAT'S ALL FLASH AND NO BANG

Making a smartwatch requires striking a balance between function and design to keep the price from reaching ludicrous levels. Louis Vuitton decided to make life easier by making a smartwatch that costs a whopping £3,245. You can't download apps for it though, as its outdated processor can only perform five functions. So where is all your money going? 24 LED lights that animate the screen, of course!

Tambour Horizon
£3,245, louisvuitton.com

SFP380

BBC Science Focus MAGAZINE SUBSCRIPTION ORDER FORM

Please complete the order form and send to:
FREEPOST OUR MEDIA *(please write in capitals)*

UK DIRECT DEBIT

☐ Yes, I would like to subscribe to/renew *BBC Science Focus* and receive 3 issues for £5. After this my subscription will continue at £22.99 every 6 issues

YOUR DETAILS (ESSENTIAL)**

Title _____ Forename _____
Surname _____
Address _____
_____
_____ Postcode _____
Home phone no _____
Mobile phone no** _____
Email** _____

☐ **I wish to purchase a gift subscription**

GIFT RECIPIENT'S DETAILS (ESSENTIAL)**

Title _____ Forename _____ Surname _____
Address _____
Postcode _____ Home phone no _____
Mobile phone no** _____
Email** _____

Instructions to your bank or building society to pay by Direct Debit DIRECT Debit

To: the Manager (bank/building society)

Address

Postcode

Name(s) of account holder(s)

Bank/building society account number

Branch sort code

Reference number (internal use only)

Originator's identification number

4 4 3 7 7 3

Please pay APS RE Our Media Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with APS RE Our Media Ltd and, if so, details will be passed electronically to my bank/ building society.

Signature

Date / /

Banks and building societies may not accept Direct Debit mandates from some types of account

KEEP IN TOUCH

BBC Science Focus Magazine would love to email you with updates, special offers and promotions. You can unsubscribe at any time. **Please tick here if you would like to receive these (You can unsubscribe at any time.) ☐

We'd also love to tell you about other offers and promotions from our publisher, Our Media Limited. If you'd rather not be contacted this way please tick here ☐ Post ☐ Phone.Your data will be held by Immediate Media Company Limited (a parent company of Our Media Limited). For information about how we protect your personal data, please see our privacy policy, which can be viewed online at **immediate.co.uk/privacy-policy**

OTHER PAYMENT METHODS

☐ **UK cheque/credit/debit card** – £57.75 for 14 issues, **saving 25%**
☐ **Europe** inc Eire – £92.54 for 14 issues
☐ **Rest of world** – £102.90 for 14 issues
☐ I enclose a cheque made payable to Our Media Ltd for £ _____

Visa ☐ Mastercard ☐ Maestro ☐

☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐

Issue no ☐☐ Valid from ☐☐☐☐ Expiry date ☐☐☐☐

Signature _____ Date _____

If credit card address is different, please use the order hotline 03330 162 113

OVERSEAS Please complete the order form and send to: *BBC Science Focus Magazine*, PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF

***Offer ends 14 September 2022.** Offer only available to UK residents paying by Direct Debit. Your subscription will start with the next available issue. After your first 3 issues your subscription will continue at £22.99 every 6 issues, saving over 30% on the shop price. If you cancel within two weeks of receiving your second issue, you will pay no more than £5.

You may photocopy this form

EASY WAYS TO ORDER

ONLINE

buysubscriptions.com/SFP380

PHONE

03330 162 113†
(please quote SFP380)

POST

FREEPOST IMMEDIATE MEDIA
(please write in capitals)

† UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages, call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am-5pm. *If calling from overseas, please call +44 1604 973 721.*

FSC MIX Paper from responsible sources FSC® C020508

SUMMER SALE INTRODUCTORY SUBSCRIPTION OFFER!

3 ISSUES FOR £5

WHEN YOU SUBSCRIBE TO *BBC SCIENCE FOCUS* TODAY*

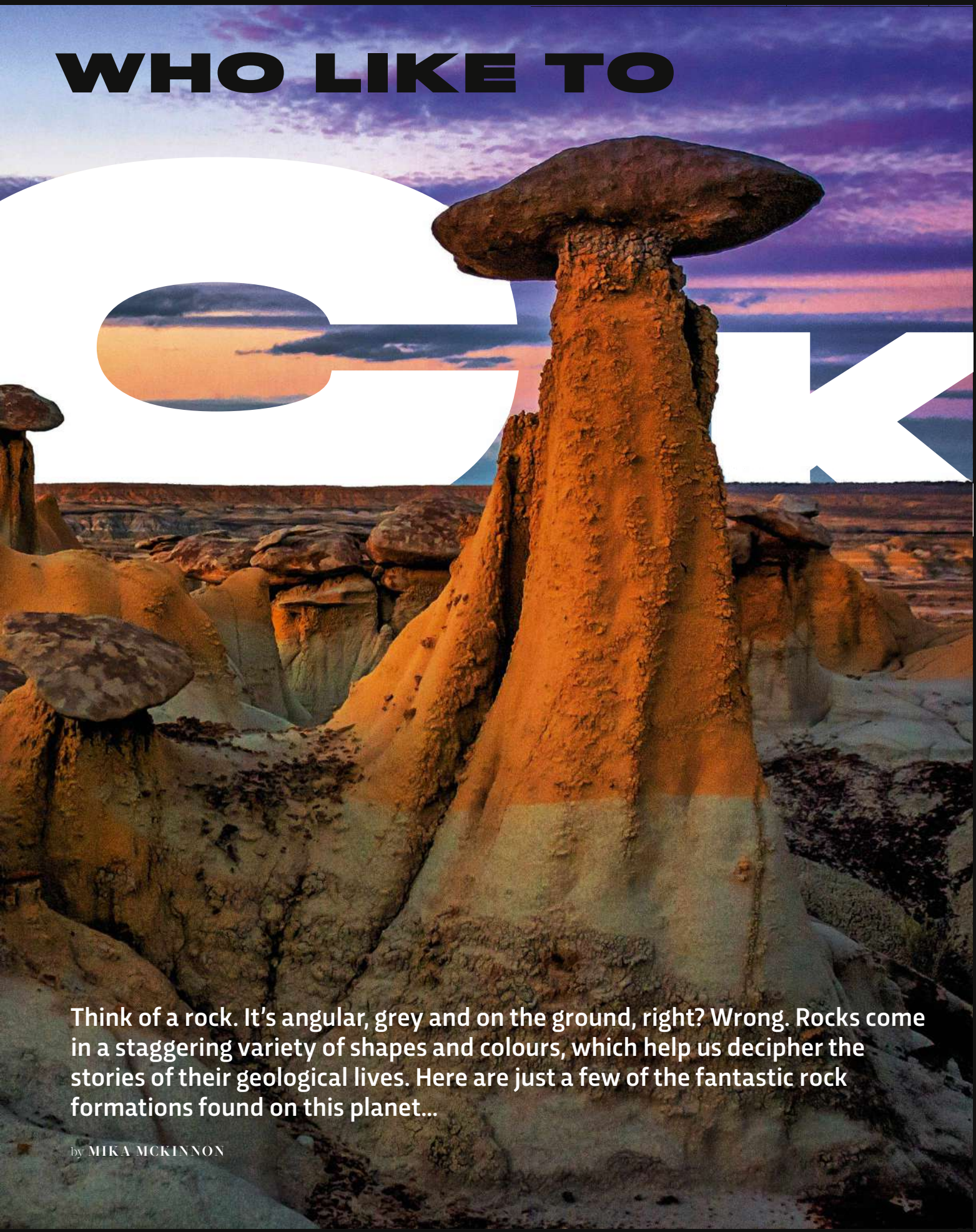
- Trial **3 issues for £5** by Direct Debit!
- After your trial period, continue to **save 30% on the shop price**, paying just **£22.99 every 6 issues** by Direct Debit!*
- Receive every issue delivered direct to your door with **FREE UK delivery**

YOUR FIRST 3 ISSUES FOR JUST £5!*

FOR THOSE

GETTY IMAGES

WHO LIKE TO ROCK



Think of a rock. It's angular, grey and on the ground, right? Wrong. Rocks come in a staggering variety of shapes and colours, which help us decipher the stories of their geological lives. Here are just a few of the fantastic rock formations found on this planet...

by MIKA MCKINNON

↑

BALANCING ACT

AH-SHI-SLE-PAH WILDERNESS, NEW MEXICO, USA

"The Ah-Shi-Sle-Pah Wilderness can feel like an alien planet, with its strange shapes, colours and lack of vegetation," says Stan Allison, of the Bureau of Land Management Farmington Field Office. The hoodoos – irregular columns of rock – dotted around the landscape also help create that otherworldly quality.

Hoodoos are a lesson in differential erosion: the stronger sandstone resists the erosion that acts on the softer surrounding rock to create spires and precariously balanced capstones. Elsewhere, the ground is so soft that rain cuts vertical sinkholes into hills, carving mazes of ravines and gullies.

The Ah-Shi-Sle-Pah Wilderness is also home to fossilised turtles and crocodiles – a lurking reminder that the parched desert was a humid swamp only 75 million years ago.

→

BED OF NAILS

TSINGY DE BEMARAHA NATIONAL PARK, MADAGASCAR

This vast field of rocky spires is the spectacular remains of a lagoon from the age of the dinosaurs. The clints and grykes (patches of limestone pavement separated by cracks) are enhanced by a subterranean labyrinth of caves that collapse and deepen the grykes.

The structure began to form 200 million years ago when calcium carbonate built up on the bottom of the lagoon. It was compacted into limestone before being exposed by tectonic uplift and falling sea levels. In the millennia since then, monsoons carved out the soft rock while acidic rain etched scalloped edges along the jagged needles.

The rocks create microclimates and isolated biomes filled with a rich diversity of life, and scientists have documented endangered and unique species within the harsh landscape.

←

CRYSTAL TOWERS

MONO LAKE, CALIFORNIA, USA

Dammed by ancient lava flows, Mono Lake is where nearby streams and rivers come to an end. Without any outflow, minerals and salts build up as water evaporates. Calcium dissolved in spring water erupting from the lake's bed reacts with the high concentrations of carbonate in the alkaline lake, crystallising to form tufa towers.

Originally forming underwater, the tufa towers have been exposed by falling lake levels. Their intricate forms contain secrets of their environmental history, with different minerals reflecting the changes in temperature over the millennia. The towers' locations tell stories of former lake levels over tens of thousands of years, and how that may be linked with greater climatic events, such as changing sea levels, ice ages and the movement of the polar jet stream.

While the exposed towers are slowly weathered and eroded by the elements, new towers continue to form below the water, currently revealed only by trails of bubbles breaking the surface.

INAKI RELANZON, ALAMY, GETTY IMAGES

→

RISING UP AND BREAKING DOWN

REYNISDRANGAR, ICELAND

During the last Ice Age, Reynisfjall, a volcano located beneath a glacier, erupted. Lava quickly cooled as it hit the ice, hardening into dark, basaltic rock. The rock contracted as it cooled, causing web-like cracks to form. This created the towering hexagonal columns of Reynisdrangar sea stacks that loom over Reynisfjara beach.

Fierce winds and waves from the Atlantic cut away at the cliffs, with salt crystals helping to open those cracks further until rocks break free. Relentless waves grind those rocks even smaller, replenishing the black sand of Reynisfjara beach.

Geologically, the Reynisdrangar sea stacks visible from the beach are the most resistant rocks that survived while the rest of the cliffs eroded away. But local folklore tells a tale of trolls wading into the ocean to chase a ship, only to get caught and turned to rock by dawn sunlight.

While spectacular, the ongoing erosion makes Reynisfjara a treacherous destination, prone to sudden rockfalls and powerful waves.

←

RAINBOW MOUNTAIN

CUSCO, PERU

Hidden high in the Peruvian Andes and only recently revealed by melting glaciers is a 20-million-year-old mountain of many colours. Vinicunca ('rainbow') Mountain is part of the range formed by the Nazca plate subducting under the South American plate.

The slopes owe their brilliant colours to traces of metals and minerals. The warmer hues are from iron oxide clays and iron sulphides, while the lavender colours come from mudstone and opal. Green layers of phyllite sparkle with mica blended with chlorites.

While now protected from miners that were tempted by the metals in the soils, Rainbow Mountain is still under threat. The soft soils compress easily underfoot, so to preserve it, the mountain is currently closed to tourists.

GETTY IMAGES X2

↑

ONCE SHIFTING SANDS

COYOTE BUTTES, ARIZONA/UTAH BORDER, USA

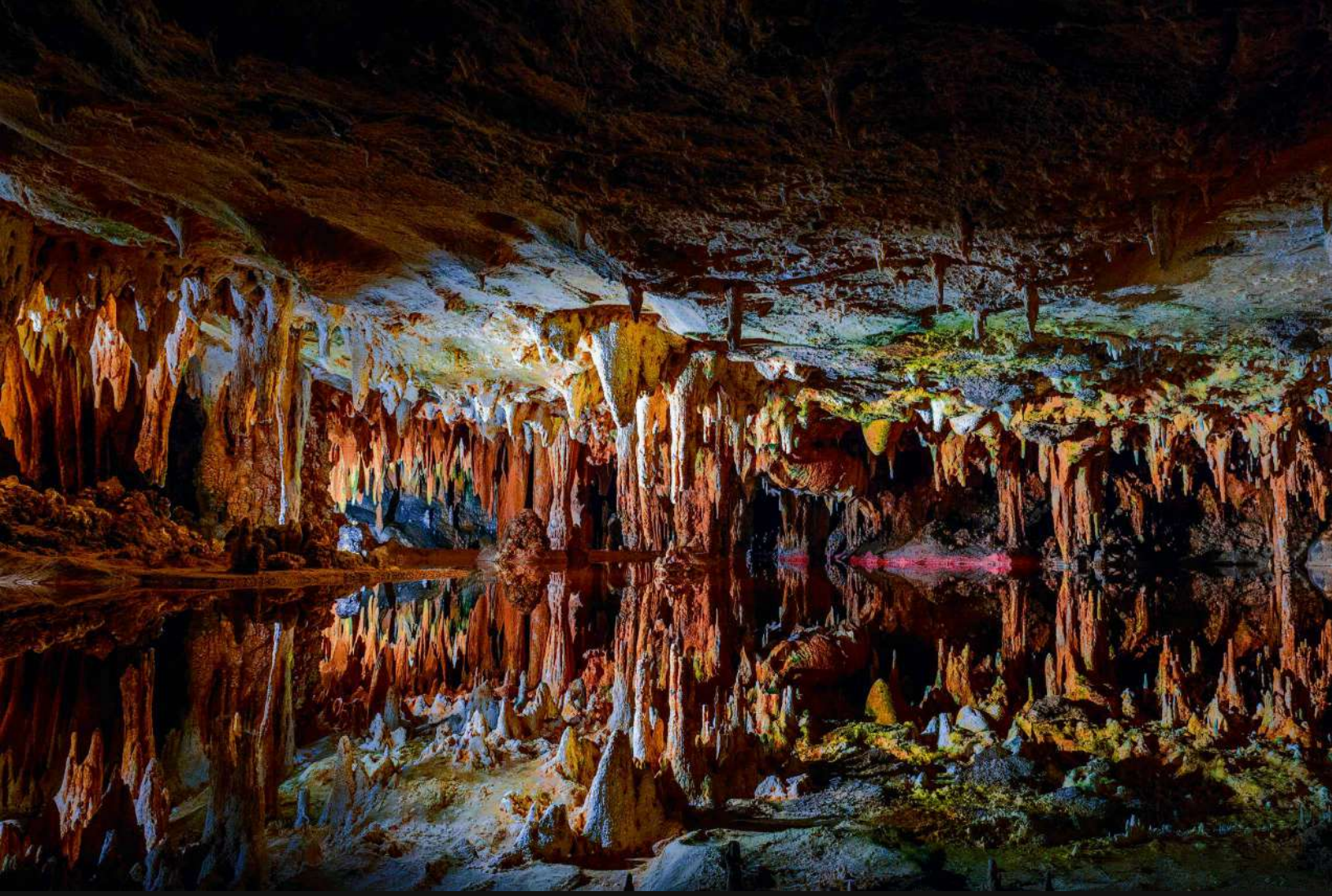
Back when dinosaurs roamed the Earth, wind blew sand across vast dunes in what is now Arizona. As the winds changed direction, the sand built up one way then another, gradually forming rippling, cross-bedded layers.

Dinosaurs crossed the dunes, leaving footprints in the muddier slurry, along with swirled sediment from tiny landslides.

Over the years, water rich with iron and manganese salts cemented the dunes into bright red rocks, petrifying their dramatic, swirling shapes. As the supercontinent Pangaea broke apart and tectonic forces lifted the rocks, rain and wind carved troughs between the dunes, funnelling greater airflow into the gaps that increased the erosion even more and helped create the formations we see in Coyote Buttes today.

"The dunes are frozen in time, capturing the shape of the ancient slopes that, in some places, are slumped and contorted," explains University of Utah geoscientist Dr Brenda Brown.

"The rocks here tell a marvellous and complex story of changing environments that are affected by so many factors: climate, life, chemistry and time," Brown says. "We can see how the chemistry of groundwater has changed through time and how those changes are recorded in the colourful minerals that cement them together."



↑

REFLECTING POOL

LURAY CAVERNS, VIRGINIA, USA

Almost half a billion years ago, ancient tidal flats and a warm, inland sea filled the Shenandoah Valley. The sediment of the flats hardened into limestone, shale, sandstone and dolomite, only to be crumpled into the Appalachian Mountains as the North American and African plates collided.

For millions of years since then, rain has been dissolving the softest of these rocks, infiltrating its way deep underground to create rivers that hollowed out vast caves.

As mineral-rich water dripped into Luray Caverns, it created thin deposits of crystallised calcite that formed into fantastic shapes called speleothems, some tinted red, yellow or brown by the iron oxides of ancient red ocean clays. The walls are coated in huge, sheet-like flowstones where water trickles down corrugated cave walls.

The shapes continue to evolve, with deposits and crystallisation adding, inch by slow inch, to the dangling spikes.

→

ROGUES' GALLERY

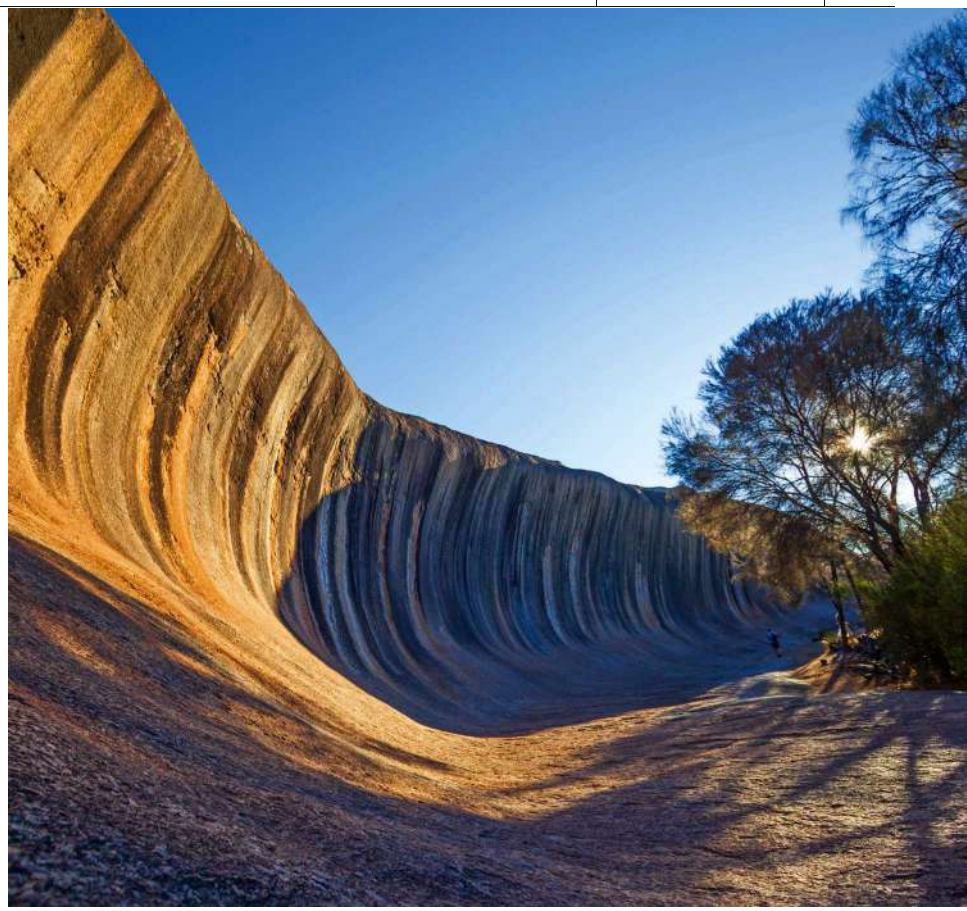
BRYCE CANYON, USA

Bryce Canyon is home to the world's largest hoodoo field. According to the Southern Paiute people, hoodoos are individuals that were transformed to stone by the trickster god Coyote, as punishment for bad deeds. Geologists have a different explanation for the origin of these strange stone columns. Water from rain or melted snow seeps into cracks along the crater rims and expands as it freezes overnight, before thawing again as temperatures climb. This freeze-thaw cycle is repeated until eventually the rock breaks. Slightly acidic rain falling onto the limestone and calcium carbonate also eats away at these weaker rocks, while stronger rocks remain untouched, enhancing the dramatic shapes.

The hoodoos of Bryce Canyon are a temporary sight – once broken free of the canyon rim, the hoodoos continue to erode at an average of 60 to 130cm per century. In about three million years the canyon will have backed into the Sevier River.

by **MIKA MCKINNON** *(@mikamckinnon)*
Mika is a field geophysicist and co-investigator of Project ESPRESSO. She was a science adviser for the television series Stargate Atlantis *and* Stargate Universe.

ALAMY, GETTY IMAGES X2



→

SURF'S UP

HYDEN ROCK, AUSTRALIA

The 110m-long, 14m-tall granite outcrop of Hyden Rock looks like a petrified wave crashing in the desert. The structure is an inselberg, an isolated mountain of hard rock, that jutted above the flat plains of the outback desert 60 million years ago. Exposed like this, the rock has been carved by rain, blasted by sand, cracked by frost and smoothed by rivers to create the distinctive shape.

During the wet season, runoff stains the rock face with stripes of iron oxides and carbonates in red, brown, yellow, and grey.

The indigenous Ballardong people of Western Australia say that the 'wave rock' was formed by the wake left by the Rainbow Serpent's crossing after she'd swallowed all the water of the land. **SF**

A MULTITUDE OF MULTIVERSES

The word 'universe' once described everything that exists. But as our horizons have expanded, many scientists have begun to consider what's beyond our own cosmos, and whether there may be many other universes lurking tantalisingly out of sight

by ROBERT LEA

SCIENCE PHOTO LIBRARY

You might have noticed, if you've set foot in a cinema this year, that Hollywood has fallen in love with the multiverse. From Marvel to DC to Disney, alternate universes, realities and timelines are being written into scripts to wow audiences and make life a bit easier when A-list celebrities tire of yanking on the latex.

It's not just the big studios that are at it. The sublimely joyful indie film *Everything Everywhere All At Once* asks and answers, 'why, if everything *is* happening everywhere and all at once, should any of it matter?' Likewise, *Rick And Morty*, *Dark* and *Man In The High Castle* use the idea of alternate universes as a kind of funhouse mirror to ponder (sometimes) serious questions about our own Universe. And it's fair to point out that the idea is nothing new. Who could forget Spock's evil doppelgänger with his suitably sinister goatee? Clearly, the idea of the multiverse has permeated the fabric of our culture.

But what do the scientists think about multiverses? Is there science to back them up?

Many physicists believe that multiverses could exist, ranging from universes lurking behind the event horizons of black holes, to growing universes expanding like bubbles in soap foam.

"A multiverse is something which is really not that strange if you think of it historically, from the point of view of science," says Prof Ulf Danielsson, a theoretical physicist at Uppsala University, Sweden. "Our horizons have continuously been expanding. At some time, we thought that Earth was the only planet and that this was the whole world. We now know there's a Universe full of other planets. It's also quite natural to speculate that there is another step and that our Universe is not the only one."

So what are some of the leading multiverse theories, and which of them could harbour an evil, possibly moustachioed, you.

The cosmological inflating multiverse

This is a theory that has grown out of cosmology, particularly from the discovery that our own Universe is expanding. This concept of a multiverse asks if the initial rapid inflation that our Universe underwent some 13.8 billion years ago, could be happening in distant regions of space-time disconnected from our Universe.

"The basic idea is that our Universe is one particular patch of space-time that is evolving as a well-defined entity," explains astrophysicist Prof Fred Adams, from the University of Michigan. "This region is homogeneous, isotropic [the same in all directions] and expanding in a well-defined manner. If you trace the evolution backward in time, then you find an age for the Universe of about 13.8 billion years from this initial expansion."

Adams, who wrote the book *Our Living Multiverse* and authored a *Physics Report* paper on the topic, also believes that other regions of the multiverse could be experiencing their own Big Bangs, and therefore their own expansions. This means that they are not able to affect our Universe. "They are thus other universes and the collection of all such universes is the multiverse," Adams says.

This multiverse idea caught on in fiction because it is an excellent storytelling device. It became popular in cosmology because it could address lingering mysteries, while still fitting with existing physics.

"One reason that the concept of the multiverse became popular is that it can naturally arise from the theory of inflation," explains Heling Deng, a postdoctoral researcher in cosmology, particle physics and astrophysics at Arizona University.

"It was shown by [physicists] Andrei Linde and Alex Vilenkin, in separate works, that if inflation did occur, it could create infinite disconnected regions."

Although inflation ended 13.8 billion years ago in the Universe we are living in, Deng says that quantum effects can always bring inflation back in another region of space-time. This results in bouts of inflation never ending – referred to as 'eternal inflation'– and the possibility of an infinite number of 'different universes'.

Russian-American theoretical physicist Andre Linde puts forward one suggestion for the arrangement of this multiverse. He sees the universes as 'bubbles' expanding on something resembling a cosmic canvas, squeezing away from each other in bouts of eternal and chaotic inflation.

How these universes within a multiverse would differ is also currently the topic of speculation, but Adams suggests there's no reason to believe that the laws of physics would be the same in these separate regions.

"One reason that these other universes are of interest is that they could have other versions of the laws of physics," he says. That variation could apply across a range of physical parameters, including gravity and the rate at which that universe expands.

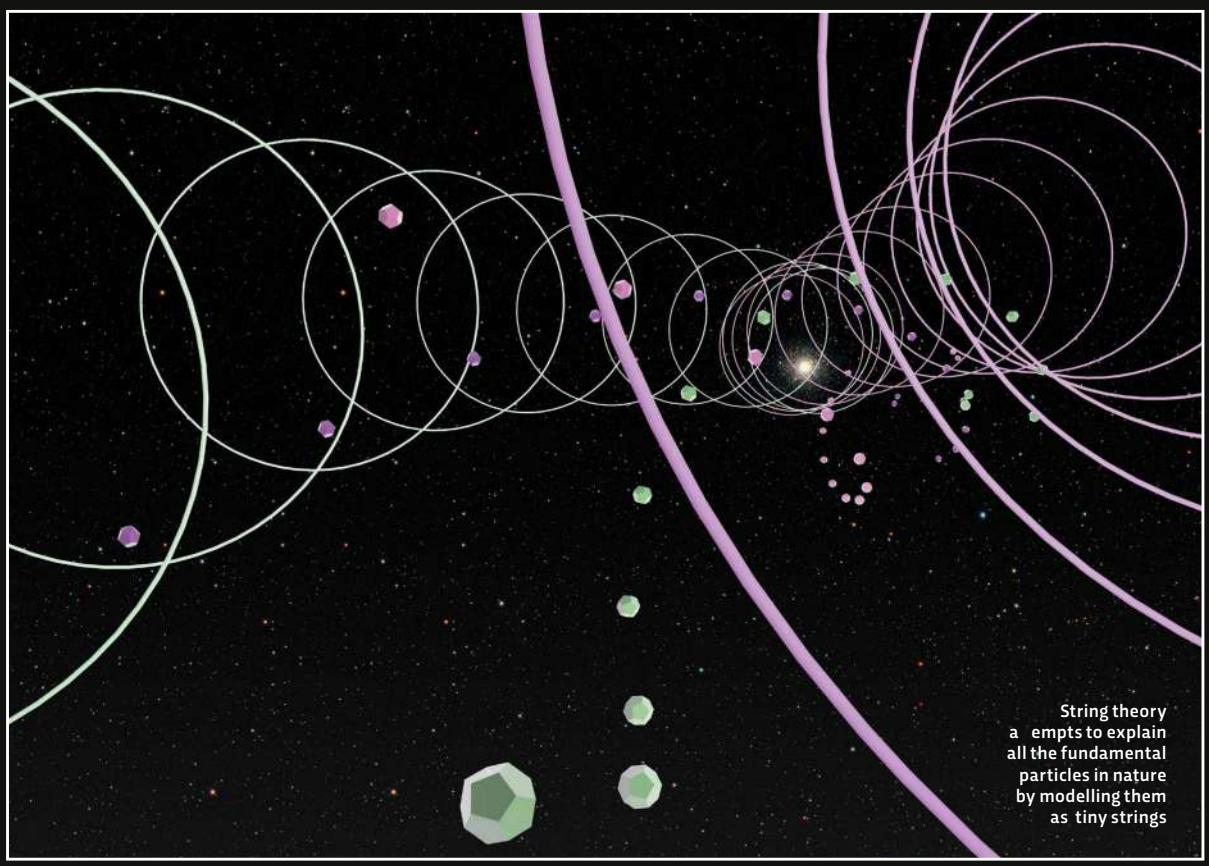
That means some of these universes could have laws of physics that aren't fit for the formation of large-scale structures like galaxies or stars. They may not even have the same fundamental particles.

Consequently, these universes aren't variations of our Universe and thus could not host any life at all, never mind some version of you or I.

"ONE REASON THAT THE CONCEPT OF THE MULTIVERSE BECAME POPULAR IS THAT IT CAN ARISE FROM THE THEORY OF INFLATION"

BELOW Our Universe underwent a period of initial rapid inflation shortly after the Big Bang

The string theory multiverse



String theory attempts to explain all the fundamental particles in nature by modelling them as tiny strings

String theory is a suggestion put forward by physicists to connect quantum mechanics and General Relativity, which are the best descriptions we have of the infinitesimally small and incomprehensibly large. The underlying idea of string theory is that fundamental particles like quarks and electrons are actually a single point in one-dimensional strings, vibrating at different frequencies.

This 'string-landscape' provides a popular setting for the multiverse, thanks to one of the key elements upon which string theory depends. In order to be mathematically sound, string theory needs 'extra dimensions' to exist.

These aren't parallel dimensions like we see in science fiction. Instead, string theorists believe these extra dimensions are curled up within the three traditional dimensions of space. They remain invisible to us, as we evolved only to see in three dimensions. These extra dimensions could offer a 'way in' to the string theory multiverse.

"You need to have these extra dimensions, and the number of dimensions needed in total is 10 or 11," Danielsson says. "It could also be that you would need to go into some extra dimension in order to get to these other universes."

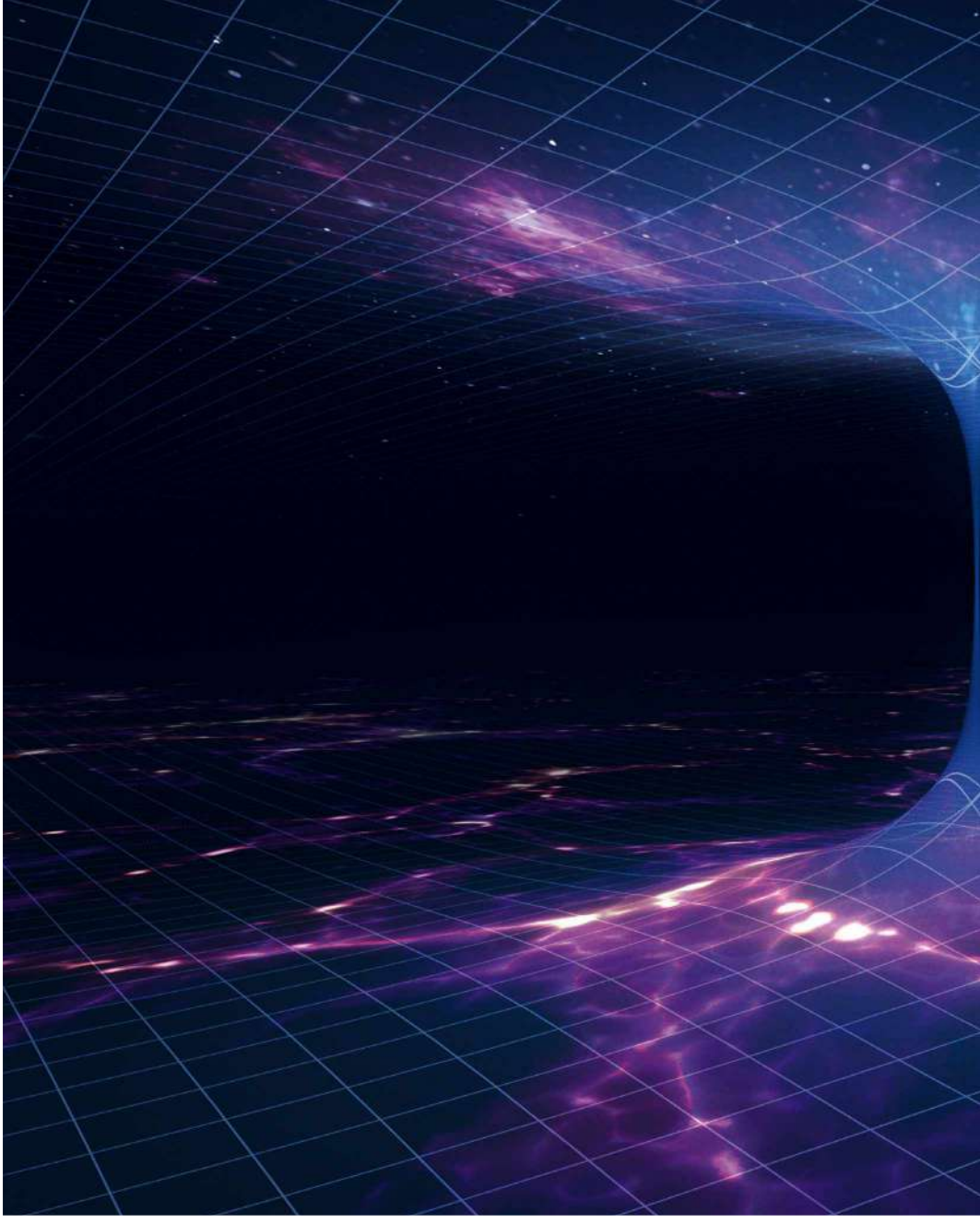
Even if this was the case and a connection via these dimensions of space to other universes existed, they may still remain permanently out of reach and view, thanks to the fact that the inflation of the Universe means that there is a cosmic horizon beyond which we can't see. If there is no 'connectivity' between universes in a multiverse, it makes the cosmological concept of a multiverse almost impossible to test experimentally.

"The 'evidence' to date is theoretical, not experimental. And, unfortunately, we just cannot do any direct experiments to verify or falsify what goes on in other universes," Adams explains.

Our inability to test these ideas is a double-edged sword. While the lack of ways to test a multiverse means we can't prove its existence, it also means we can't disprove it either.

SCIENCE PHOTO LIBRARY X2

The black hole multiverse



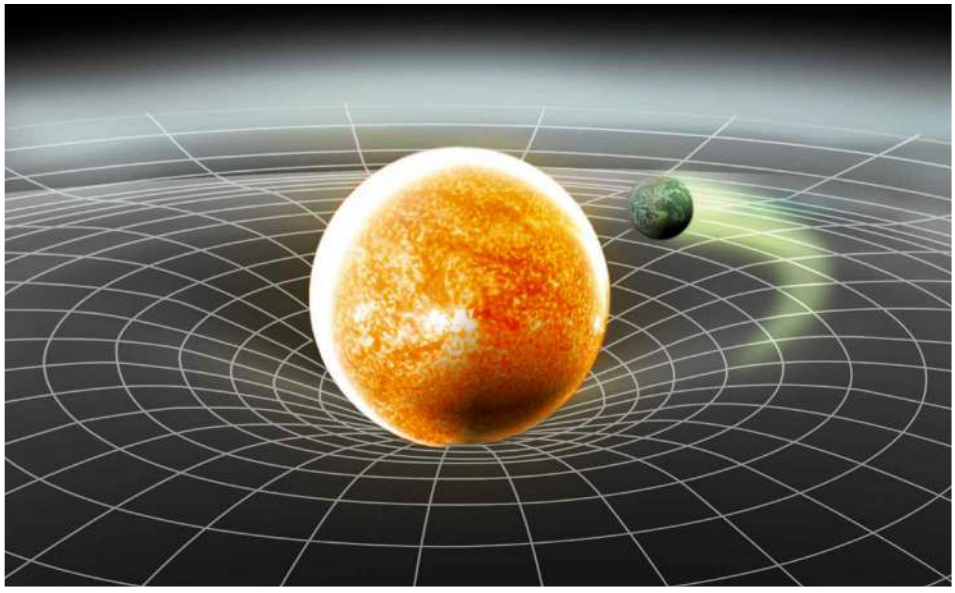
At the end of a massive star's life, when it has run out of fuel for nuclear fusion, it'll collapse into a black hole – a region of space-time bounded by a surface called an event horizon from which nothing, not even light, can escape.

Einstein's General Theory of Relativity tells us that a large mass can curve space-time. The theory also says that the heart of a black hole has a singularity where the mass is so great that the space-time curvature becomes infinite and, consequently, the laws of physics break down. This is a concept that troubles physicists, but one hypothesis could do away with the singularity and replace it with an entire universe and in turn, a multiverse.

"Singularities are unphysical because they cannot be measured. That means their existence indicates that a theory is incomplete," says theoretical physicist Dr Nikodem Poplawski, from the University of New Haven, Connecticut. "In my hypothesis, every black hole produces a new, baby universe inside – on the other side of the event horizon – and becomes an Einstein-Rosen bridge, also known as a wormhole, that connects this infant universe to the parent universe in which the black hole exists."

In this theory, when viewed from the new universe, the parent universe appears as the other side of a white hole, a region of space that cannot be entered from the outside and which can be thought of as the reverse of a black hole.

"An analogy of the matter going to a black hole and ending up in a new universe could



SCIENCE PHOTO LIBRARY X2

ABOVE A black hole could spawn a new, baby universe

LEFT According to Einstein's General Relativity, large objects cause space-time to curve

"A UNIVERSE MAY PRODUCE BILLIONS OF BLACK HOLES AND EACH OF THEM COULD PRODUCE A BABY UNIVERSE"

be blowing a soap bubble through a circular wand," Poplawski says. "The wand is the event horizon – albeit in one dimension less – the soap liquid is the matter crossing the event horizon, and the surface of the bubble is the new universe."

In the hypothesis suggested by Poplawski, a universe may produce billions of black holes and each of them could produce a baby universe. In January of this year, researchers at the International School of Advanced Studies (SISSA) in Italy estimated that there could be as many as 40 trillion – that's a four followed by 13 zeros – black holes in our Universe alone. That's a lot of baby universes!

These infant universes would be hidden from the occupants of their parent universe by the light-trapping surface of the event horizon, and once that event horizon is crossed there's no going back. That, and the fact nothing can enter a white hole (which is still purely theoretical but allowed by General Relativity), means no interaction between parent and infant.

However, if two black holes existed in the same universe, and each of these black holes created a new universe, then there is a possibility that these two sibling universes could merge, "just as two black holes merge to create one black hole," says Poplawski.

He adds that this would manifest in a baby universe as a large-scale asymmetry in space. This means that if we ever discover some preferred direction in our Universe – a direction with increasing matter and energy, for example – it could be attributed to our Universe interacting with a sibling.

As for the possibility of an alternate version of you existing beyond the event horizon of a black hole, Poplawski concludes that chances are not good. "There would be no 'alternate you.' At any time, an object can only exist in one universe," he says.

But one pop culture mainstay reflects his concept: "I think the closest thing could be the TARDIS in *Doctor Who*. You enter the police box and you realise that you are in something bigger than the box."

The many-worlds multiverse of quantum mechanics

In quantum physics, which deals with the physical laws of the subatomic, the term multiverse doesn't exist. Alternate universes are instead referred to as 'many worlds' and are part of a radically different concept, as these aren't geographic in nature like the multiverses explored previously.

The many-worlds hypothesis was first suggested by the US physicist Hugh Everett III to explain how a quantum system can exist in seemingly contradictory states at the same time – called a 'superposition' – and how these paradoxical states seem to vanish.

The effect of many worlds on the existence of a superposition of states can be imagined by considering Erwin Schrödinger's infamous thought experiment, Schrödinger's cat.

In the thought experiment, a hapless moggy is placed in a sealed box with a device containing a vial of lethal poison, released only if an atomic nucleus in the box decays. Treating the box, the cat and the device as a single quantum system, each state – in this case, 'dead' or 'alive' – is described by a wave. As waves can overlap to form a single wave function, the cat can exist in a superposition of states. This means that in quantum mechanics the cat is both simultaneously dead or alive.

This seemingly contradictory state persists only until the box is opened – analogous to making a measurement on the system – and the wave function collapses meaning the superposition is gone and the state is resolved. The cat is either dead or alive. Yet *why* measurement causes this collapse of superposition, also known as 'decoherence', is still a mystery.

The many-worlds hypothesis does away with decoherence altogether. Instead, it suggests that rather than the opening of the box collapsing the wave function, measurement causes it to grow exponentially and 'swallow' the experimenter and eventually the entire Universe.

"In the many-worlds formulation of quantum mechanics, each state of a system is a physically distinct world," says Prof Jeffrey Barrett, a philosopher of science at the University of California Irvine.

This means each flick of a light switch would create a near-infinity of worlds. One for each possible path of each photon as the light fills your living room, not just a world in which you didn't flick the switch at all.

That means that in terms of the Schrödinger's cat thought experiment, the experimenter isn't opening the box to discover if the cat is dead or alive. Rather, they are opening the box to discover if they are in a world in which the cat is dead, or one in which it lives.

At first, the worlds that comprise this quantum multiverse are similar, with infinitesimally small differences. But these changes grow from universe to universe, meaning those that diverged earlier could be strikingly different from each other.

"The objects, events and physical records of observers are different in different worlds. There is a world where the Eiffel Tower is in Los Angeles," Barrett says. "All of the worlds

ABOVE
Schrödinger's cat can help explain superposition, but also quantum multiverses

SCIENCE PHOTO LIBRARY, BBC

"THERE IS A WORLD WHERE THE EIFFEL TOWER IS IN LOS ANGELES"

– universes – are part of a single global universe. It looks just like this universe from the perceptive of our branch world."

Barrett addresses the question of how likely it is that one of these 'many worlds' would contain an alternate 'you'. He reveals that it isn't just possible, it's demanded.

"It certainly would contain many alternate copies of me," he says. "That is fundamental to how the theory addresses the quantum measurement problem."

All of this makes the quantum version of the multiverse the one that most closely resembles pop culture, at least in principle. This is because it doesn't just *probably* contain infinite versions of you, it *definitely* does. SF

by ROBERT LEA (@sciencef1rst)
Robert is a freelance science journalist, specialising in space, physics and astronomy.

PLOT TWIST

Every tale that exploits a multiverse needs a MacGuffin, a device that allows access to these weird worlds. Here are some of our favourites…

1. THE FLASH'S ROPE TRICK

In a 1960s comic book, superhero the Flash visits an alternative world. He does so by performing his own version of the Indian rope trick, which sees a person climb a length of rope and disappear. To perform the trick, he vibrates his hands at super-speed, which causes the rope to rise into the air. He then climbs up the rope and phases into a different universe. Maybe string theory is founded on vibrating ropes in the DC Universe?

2. LEGION KILLING HIS DAD

The X-Men's mentor Professor X has a contentious relationship with his son David Haller, known as Legion. In a 1995 story, Legion travels back in time to kill his father's nemesis Magneto, but accidentally murders Professor X. This leads to a twisted world in which the X-Men enemy Apocalypse rules, and Magneto forms a very different X-Men team. The many-worlds theory would suggest that Legion travelling back in time created a new 'world'. This is something that has been suggested as an 'out' for the grandfather paradox, in which a time traveller kills his own grandfather before his parent is conceived. Rather than causing the time traveller to no longer exist, in the many-worlds theory the event would cause worlds to split, ensuring the time traveller's existence in the primary world he left.

3. THE TARDIS

Doctor Who's time-travelling police box isn't supposed to travel to parallel worlds, but this is exactly what it does in David Tennant's run in *Doctor Who*. This allows the Doctor to watch the rise of his enemies the Cybermen all over again, as they dominate a new world. *Doctor Who* lore posited a void between universes, perhaps similar to the voids that separate bubble universes in a cosmological multiverse.

It was a bad day for Doctor Who when he saw the Cybermen rise *again* in another universe

BBC WORKLIFE

For information and tips about working in today's world, visit **bbc.com/worklife**

WORKING FROM HOME VS THE WORKPLACE: A SCIENTIFIC ANALYSIS

WORDS: DR DEAN BURNETT ILLUSTRATIONS: JOE WALDRON

More than two years ago, many of us started working from home at least some of the time. So now the novelty has worn off, are hybrid workers more productive and happier than those working full-time in an office?

The ongoing post-pandemic transition from employees working full-time in the office (or equivalent workplace) to more regularly working from home, aka remote working, has been met with many concerns, objections, and even scaremongering by employers.

However, many of the arguments against remote working seem to be emotional, or even ideological, rather than rational. Accordingly, workers have been passionately resisting plans to reduce their remote working arrangements.

But looking beyond accusations of lazy employees, or greedy landlords and managers, what does the actual science say?

ARE REMOTE WORKERS LESS PRODUCTIVE?

The issue of productivity has long been a primary focus of the world of work. Logically, employers want employees to be as productive as possible, because the organisation wants to get as much done as possible for the same wage bill. However, this obsession isn't always helpful, or even rational. Many persistent (and annoying) productivity myths have ended up circulating in society. You could even argue that the modern management obsession with 'employee happiness' is more about increasing productivity than any genuine concern for employees and their wellbeing.

Predictably, the debate around working from home quickly became embroiled with concerns about productivity. The thinking was that workers wouldn't get as much done when deprived of the resources of the workplace, the necessary management structure, the vital interactions with co-workers, and so on. Except that's apparently not true. Surveys reveal most remote workers report being equally, if not more productive. There are many factors that could be behind this, such as improved diet, better sleep, more exercise, greener environments and pleasant background music. All of these and more are linked to improved productivity, and are much more accessible for an employee when they don't have to commute, or conform to the rigid rules or strict hierarchies of many workplaces.

Granted, many remote workers report being less productive when working from home. And again, many factors could be behind this, like an unsuitable home environment, or roles that aren't as suitable for a remote setup. But one interesting study revealed that home workers who reported reduced productivity also reported worse mental health. In this case, is poor mental health a cause or effect of reduced productivity? Remember, most of the up-to-date data on this subject was obtained mid-pandemic, a context that led to widespread harm to mental health. Perhaps for many workers, being unable to work effectively from home amplified insecurities about career and finances, therefore increasing anxiety and reducing mental health? But remote workers reporting increased productivity were also experiencing the same scenario. Maybe the relief of keeping their job during such fraught times, and not having to mix with co-workers, caused reduced stress and subsequent perceived increases in productivity? Everyone's situation will have been unique, so it's hard to say for sure. While many are saying working from home will 'stick', it'll be interesting to see how it affects productivity going forwards.

CAN REMOTE WORKERS COMMUNICATE EFFECTIVELY?

Why did the pandemic and lockdowns negatively affect mental health for so many people? One reason was the increased loneliness and isolation. We humans are social creatures who thrive on interactions with others. If we're denied them (by social-distancing laws, for example), our mental health suffers.

Similarly, interactions with other people are key aspects of many modern jobs. Whether collaborating on projects, discussing strategies, planning constructions, presenting information, dealing with medical emergencies or getting constructive feedback as part of your development, it's vanishingly rare that a worker can do their job with no involvement from anyone.

Subsequently, those who object to remote working argue that it prevents effective communication, cooperation and collaboration between workers. And according to the data, they do have a point.

A major study published in *Nature Human Behaviour* in September 2021 revealed that when 60,000+ Microsoff employees worked remotely during the pandemic, communication between employees and groups slowed down, and became more formulaic and self-contained. Other studies show that team performance is reduced when some or all members work remotely.

Humans have spent millions of years communicating face-to-face, and as far as our brains are concerned, modern technology, however advanced and sophisticated, still cannot faithfully replicate all the rich and subtle cues it involves. While things like social media can help with loneliness, they can't alleviate it entirely.

The absence of normal body language cues may also explain reports of people not being as involved or engaged during Zoom meetings.

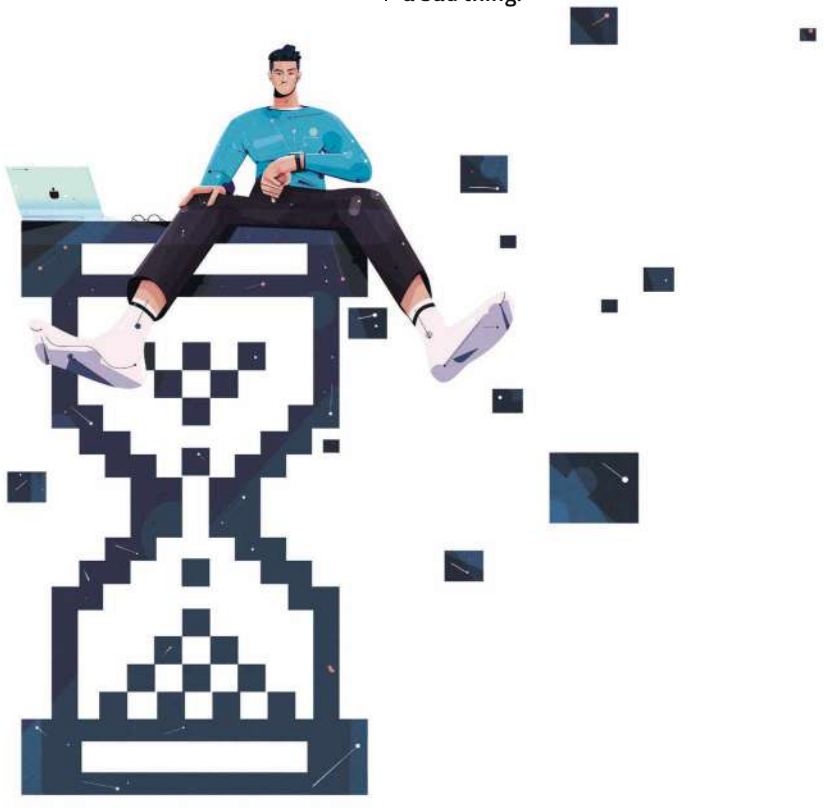
"Many people reported feeling exhausted from a day spent on Microsoff Teams," says Dr Chris Blackmore, a mental health specialist from the University of Sheffield. "Was it the level of attention needed to really engage with online meetings? The demands of listening, and keeping track of multiple voices? Or an increased background of anxiety, both from the pandemic and from new ways-of-being? For some people, the lack of physical presence and reduced body language was a barrier. They missed something about the workplace – the buzz of bumping into people, having impromptu conversations, the small talk and informal chats. This may be hard to put a value on, but it can contribute to a feeling of belonging."

While in-person engagement is the ideal, studies suggest technological communication methods, particularly multisensory ones like video calls, can help people form useful social connections and deliver viable feedback. This issue should also be placed in a wider context. Yes, employers may not like how employees aren't collaborating as much when working from home, but how much of their role actually requires collaboration? 'Higher-ups' may relish holding meetings and all-day events, but more typical workers offen bemoan the amount of time spent in long-winded meetings that could have been an email. If interaction and collaboration is something that's expected of employees, rather than actually required, remote working would mean they get more done.

Even if collaboration is a welcome and necessary part of a role, remote working can still mean enhanced performance overall. A study published in *PLOS One* in March 2021 suggests that the drop in more collaborative performance is balanced by an enhanced output on tasks that require a more focused, individual approach.

Ultimately, remote working seemingly has a negative impact on worker communication and collaboration. But when you consider that some of this 'communication' will have been deemed unnecessary, or even counterproductive, this isn't necessarily a bad thing.

"Modern technology still cannot faithfully replicate all the rich and subtle cues that face-to-face communication involves"



DOES REMOTE WORKING OFFER A BETTER WORK-LIFE BALANCE?

In the modern world, we're constantly told about the importance of a healthy work-life balance. The exact meaning of the phrase is somewhat debated, but it's generally agreed that you need to strike a good balance between how much time and energy you invest in your work, and how much you invest in your home life, family, relationships, and everything else.

A good work-life balance is difficult to achieve at the best of times, given the aforementioned obsession with 'productivity' in most workplaces, but the impact of remote working has received a lot of attention. How can you maintain a work-life balance when both occur in the same place?

It's not just a rhetorical question; it makes scientific sense, given what we know about human psychology and neurology. Our brains organise the information we use to navigate the world, and the events we experience, by way of cognitive frameworks labelled 'schemas'. We use schemas to determine how to act and respond in different situations and contexts, leading to the formation of 'social schemas'. That's why we behave in a certain way around our closest relatives, another way around old school friends, another with our university friends, and so on.

This is particularly obvious in the workplace, a familiar context with specific rules, expectations and norms. Our brains are sensitive to boundaries between places, so would logically find it easier to get into 'work mode' when entering a context set up for exactly that.

In contrast, trying to work and maintain your home life in the same place should prove more challenging. Our brains find it difficult to actively 'shift gears' like that, so it would likely require more cognitive effort to do your job in a context where you don't normally. A physical separation between your home and your workplace would be advantageous here.

"One of the big issues people can have working from home is the ability to switch from 'work mode' to 'home mode'," says neuroscientist Ginny Smith, author of *Overloaded: How Every Aspect Of Your Life Is Influenced By Your Brain Chemicals*. "Some people find it hard to concentrate on their work, getting distracted by the washing up, or the lure of the TV. Others have the opposite problem, struggling to switch off at the end of the day, and finding they are going to bed with work issues still whizzing around in their heads."

According to Smith, one thing you could do to help with this would be to have dedicated 'work zones' in your house. "If you have a spare room you can use as an office, perfect, but if not, it might just be one end of the kitchen table. But try to make sure that it's the same place every day, and it's not somewhere you usually relax or sleep," she says.

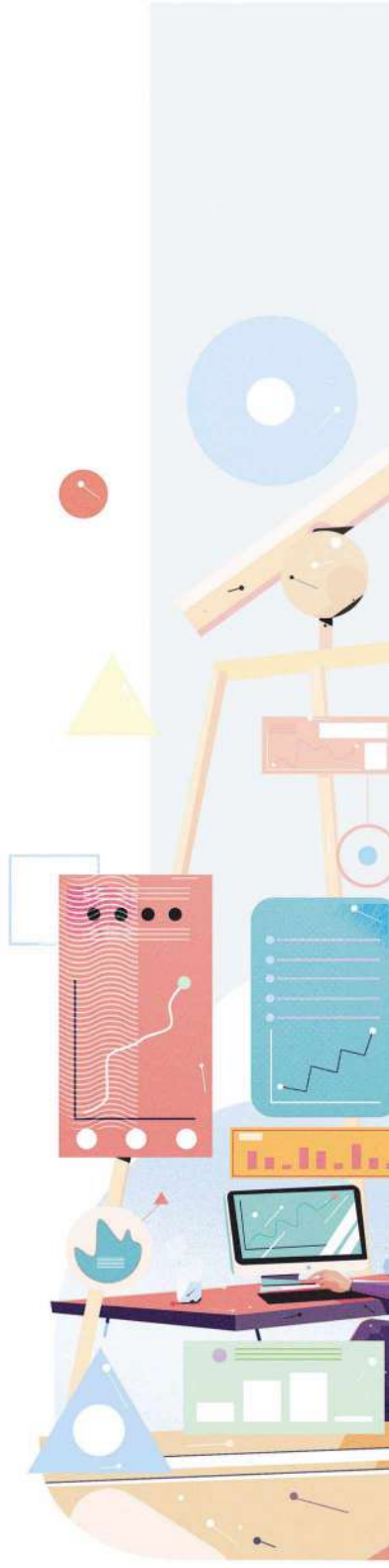
There are other things you can do to tell yourself when it's time to work. For example, you could go for a short walk at the start and end of each working day to give yourself a 'false commute'. Some people also swear by wearing shoes during their working day, then kicking them off when they finish.

> **"Some people find it hard to concentrate on their work, getting distracted by the washing up, or the lure of the TV"**

However, once again, there are two sides to this story. Yes, having a dedicated environment for working should make it easier to enter that 'work' mindset, but this doesn't factor in how much mental effort going to the workplace demands. In short, regularly going to the office can be cognitively exhausting. Long commutes, a strict schedule you don't create, interacting with people you wouldn't normally choose to, little privacy or personal space, and seeing no tangible outcome of your efforts are all regular occurrences in the workplace. These cause stress and mental exhaustion, often to the point where your mental health suffers and you lose the ability to maintain your home life.

Remote work reduces this mental drain substantially. This may explain why some studies suggest working from home some of the time reduces the demand of working from the office, rather than exacerbating it.

It's not that working from home doesn't require mental effort, because it does. But it could well be less mentally demanding than working in a designated office five days a week.



WHAT ABOUT PEOPLE WHO CAN'T WORK FROM HOME?

Ultimately, everything that's been said so far about the relative pros and cons of remote working should come with a massive caveat: what type of work are we talking about?

Most of the debate around remote working versus the workplace focuses on occupations like financial services, administration, software development, various types of creative industries, and so on. Basically, 'workplace' means 'office'.

This makes some sense, in the UK at least. Our economy is largely service-based, much of which involves office roles. And since the rise of the internet, office work is arguably the easiest to transplant to a home context. Indeed, a 'home office' is a common feature of many houses.

But not all work is based in an office, and not all jobs can be done from the home. If the pandemic taught us anything, it was how vital supermarket employees, truck drivers, carers and frontline medical staff are. At present, none of these key roles can be done from home. Not that they could never be. Some may even benefit from it, particularly in the medical field. Remote surgery has been researched for a number of years, and the pandemic saw a spike in interest in remote mental health therapies. Such things could feasibly reduce the odds of human error and widen accessibility for the vulnerable.

Nonetheless, it remains the case that there are many jobs out there that can only be done 'in person'. This is where social and cultural divisions can arise. On the global scale, first world 'developed' economies invariably involve far more jobs that can be done remotely, while poorer developing nations are considerably more dependent on construction, manufacturing and agriculture.

Studies suggest that if working from home does actually produce significant gains in productivity and worker happiness and subsequently becomes the norm, all the gains of such a move are likely to be concentrated in wealthier countries.

Such imbalances are not only on the global scale, either. It's been observed, repeatedly, that those people who do vital roles that cannot be done remotely, like cleaners, shelf-stackers and carers, are paradoxically among the lowest paid in our society. If remote working saves money and stress, such benefits are less likely to be experienced by those who could use them the most.

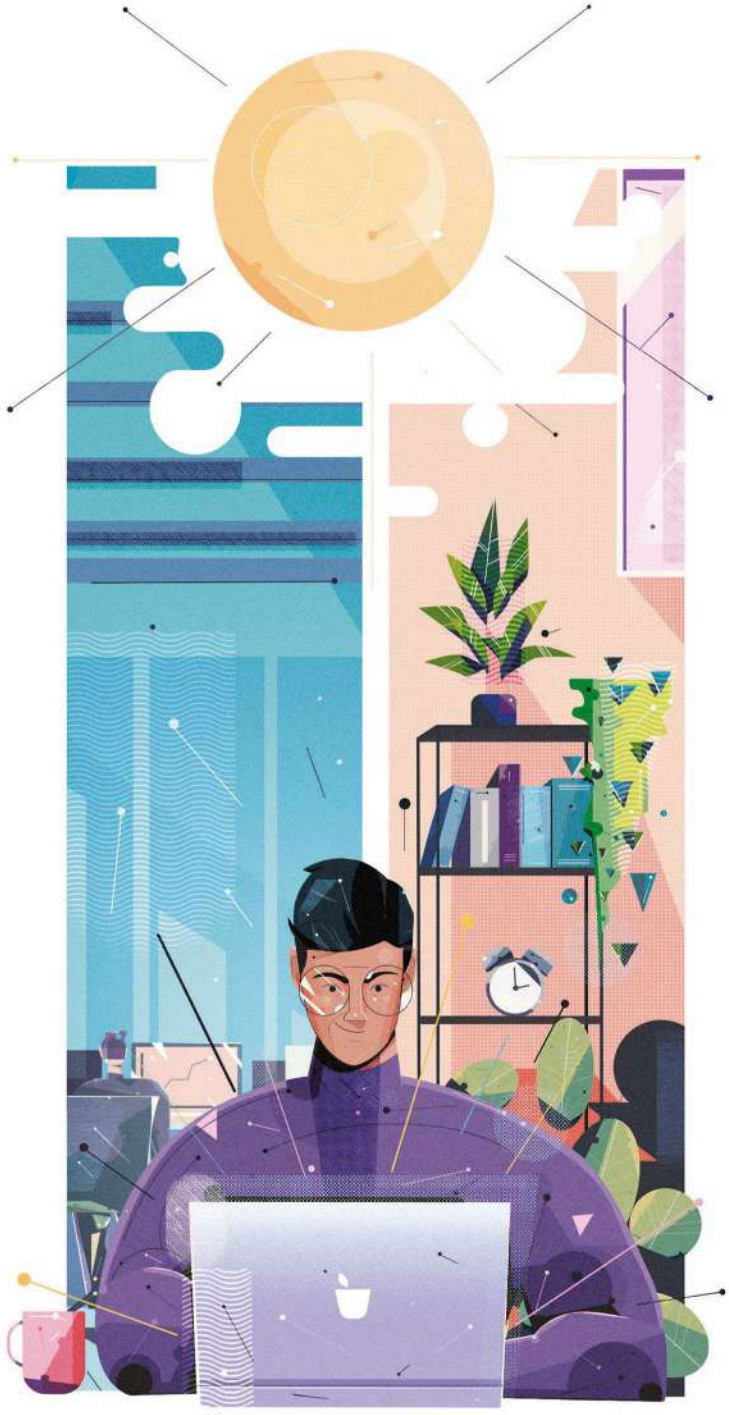
And even among those who can feasibly work remotely, there are divisions. It's all well and good listing the benefits of working from home, but what if your home isn't suitable? What if you've not got the space? Or your internet is terrible? Or if you share your home with too many others? Or if you live with someone you don't get on with, or worse?

However, using this unfortunate aspect of the modern world as an argument against remote working quickly leads to a false dichotomy. This is not a zero-sum game. If we deny those who can work from home the benefits of doing so, then it does not magically make things better for those people who can't. It ultimately just makes everyone unhappier overall.

The unfair imbalances in our society are a deeply unfortunate fact of life. Doing something about them will require sustained and widespread effort into creating lasting structural change. This, arguably, will be even harder than it already is if many people are denied the benefits of home working for no logical reason.

THE HYBRID WORKING TOOLKIT

HOW WE CAN ALL WORK EFFECTIVELY, WHEREVER WE ARE BASED



EMBRACE AUTONOMY

One core element of many of the apparent benefits of remote working is increased autonomy, from a worker's perspective. When people feel they have more control over their lives and situation, they're invariably happier, less stressed and more productive. As a result, employers actively forcing workers to return to the office would reduce their perceived autonomy even more. This would likely lead to reduced worker productivity and satisfaction.

BE FLEXIBLE

It need not be an all-or-nothing approach. Some studies suggest a blend of home and office working is the best approach, allowing workers to experience a 'best of both worlds' effect. By letting workers figure out their own balance, it means those who want to work from home can do so, and those who don't want to, don't need to.

COMMUNICATE EFFECTIVELY

Effective communication is possible via technological platforms, like video conferencing. But it does seem to require more effort and attention, so it would help to specifically allow time for this. This may be achievable by distinguishing between essential and non-essential communication, and focusing solely on the former.

KEEP AN EYE OUT FOR PROBLEMS

Much of the information we have about the pros and cons of working from home was acquired in the midst of the COVID-19 pandemic. This will have had a considerable influence over people's attitudes to it, as well as the data obtained. As the pandemic becomes less pressing as an issue, it would be useful to monitor subsequent changes in productivity and wellbeing. **SF**

by **DR DEAN BURNETT**

Dean is a doctor of neuroscience, former psychiatry lecturer and bestselling author. His latest book, Psycho-Logical *(£9.99, Guardian Faber) is available now.*

BBC COUNTRYFILE MAGAZINE

TRY 3 ISSUES FOR ONLY £5*

when you subscribe to *BBC Countryfile Magazine*

- Try your first **3 issues for just £5!***
- Continue to pay just **£19.99 every 6 issues – saving 30%** on the shop price
- **Free UK delivery** direct to your door in our new paper wrapping
- **Never miss an issue** of your ultimate guide to the British countryside!

Subscribe online or call us

WWW.BUYSUBSCRIPTIONS.COM/CFL22HA

03330 162112† Quote code **CFL22HA**

†UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 8am – 6pm and Sat 9am – 1pm. *3 issues for £5 offer is only available to UK residents paying by Direct Debit. After your first 5 issues your subscription will continue at £19.99 every 6 issues. If you cancel within 2 weeks of receiving your 2nd issue you will pay no more than £5. B*BC Countryfile Magazine* is published 13 times a year. Your subscription will start with the next available issue. Offer ends 31st December 2022.

Q&A

YOUR QUESTIONS ANSWERED

... DOES BLOWING ON A HOT CUP OF TEA ACTUALLY DO ANY GOOD?
... WHY CAN'T MARINE ANIMALS SURVIVE IN FRESH WATER?
... HOW DOES A DEFIBRILLATOR WORK?
... ARE BIG HEADS SMARTER?
... IS MARMITE GOOD FOR YOU?
... WHAT IS WEB3?
... HOW DOES ECHOLOCATION WORK?
... WHAT'S THE DIFFERENCE BETWEEN WAVE ENERGY AND TIDAL ENERGY?
... WHAT IS TETRACHROMACY AND HOW DO I KNOW IF I'VE GOT IT?
... WHY DOES WRITING MY OWN NOTES HELP ME LEARN THINGS?

Email your questions to

questions@sciencefocus.com

or submit on Twitter

@sciencefocus

OUR EXPERTS

DR CLAIRE ASHER Science journalist

PROF PETER BENTLEY Computer scientist

PROF STEVE BRUSATTE Veteran palaeontologist

LUIS VILLAZON Science and technology writer

PETE LAWRENCE Astronomy writer

DR EMMA DAVIES Food chemist

DR CHRISTIAN JARRETT Psychologist and neuroscientist

PROF DANN MITCHELL Climate science expert

DR HELEN PILCHER Biologist and science writer

DR NISH MANEK GP and health writer

DR HELEN SCALES Marine biologist and writer

ILLUSTRATION: DANIEL BRIGHT

EDDIE SMITH, VIA EMAIL

DID THE *T. REX* ACTUALLY HAVE FEATHERS?

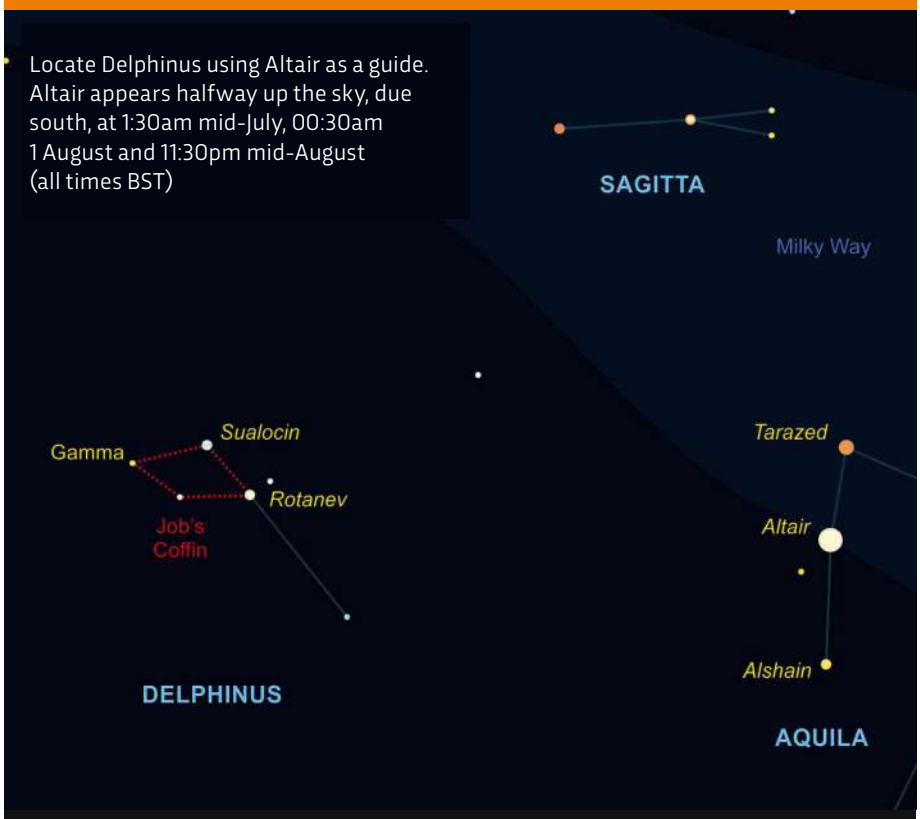
The classic image of *Tyrannosaurus rex* is a reptilian monster. A green or brown, scale-covered brute that looks like an overgrown version of a crocodile or lizard. But in recent years, a new image has been making its way into books, television documentaries and online palaeoart: a feather-covered *T. rex*. Is this true?

First, there is not yet any direct fossil evidence of feathers on a *T. rex*. Nobody has found a *T. rex* skeleton cloaked in feathers, or any feathers sticking out of a *T. rex* arm bone. But this isn't surprising. Feathers, muscle, skin, internal organs and other soft structures don't often preserve as fossils. Most fossils are of hard objects like bones, teeth and shells, which can be more easily turned to rock and survive the ravages of geological time.

With that said, we have good reason to believe *T. rex* did have some feathers. In China, in the Early Cretaceous, volcanic eruptions buried entire ecosystems similar to how the city of Pompeii was buried by Mount Vesuvius. The dinosaurs were killed and interred quickly, and their soft tissues were locked in place. Many of these dinosaur skeletons are covered in feathers, including two tyrannosaurs – close cousins of *T. rex* – called *Yutyrannus* and *Dilong*. This means that the ancestors of *T. rex* had feathers, which means *T. rex* probably did too.

As an aside, a recent study made headlines by dividing *T. rex* into three separate species, based on differences in the proportions of the thigh bone. It's a provocative study, but to me, this variation is minor, and not yet conclusive enough to show whether there was more than one type of *T. rex*. ***SB***

ASTRONOMY FOR BEGINNERS



DELPHINUS THE DOLPHIN

WHEN: LATE JULY TO AUGUST

There are many creatures depicted in the night sky. Some, such as Scorpius the Scorpion or Cygnus the Swan, do, with a bit of imagination, look like the thing they're supposed to represent. Others, such as Delphinus the Dolphin, require more work. Delphinus is a small constellation of summer, located to the left (east) and slightly north of the summer star Altair, the brightest in the constellation of Aquila the Eagle. Altair is easily identified thanks to the two dimmer, but still bright, stars that sit either side of it; Tarazed and Alshain.

The best way to describe how Delphinus appears to the naked eye, is as a small diamond pattern with a tail. The diamond pattern is also an asterism (an unofficial pattern) known as Job's Coffin. The constellation may not look too much like a dolphin at first, but that may be because you're imagining it wrong. It's supposed to represent the nose and neck of a bottle-nosed dolphin, its head poking out of the sea.

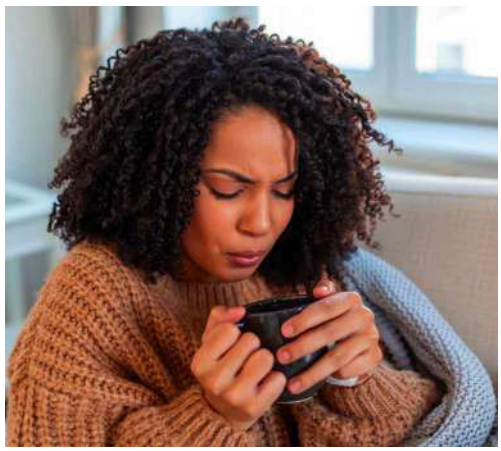
Delphinus is compact, and even though its stars aren't particularly bright, it is distinctive. The two stars on the western (right) side of the diamond have the unusual names Sualocin and Rotanev. These first appeared on the *Palermo Star Catalogue* of 1814, courtesy of the Italian astronomer Niccolò Cacciatore. It took 45 years before the British astronomer Reverend Thomas Webb worked out what Cacciatore had done to create the star names. He'd Latinised the English version of his name to arrive at Nicolaus Venator and simply reversed the letters to generate the star names as a practical joke which has stuck.

The dolphin's nose is marked by Gamma Delphini, a binary star which splits into a golden-orange primary and yellow secondary, when viewed through the eyepiece of a telescope. ***PL***

JAMES OF BRIDGWATER, VIA EMAIL

DOES BLOWING ON A HOT CUP OF TEA ACTUALLY DO ANY GOOD?

Although your breath is generally warmer than the air, blowing on a hot cup of tea does cool it a little. As water molecules evaporate from the surface, the average kinetic energy of the tea drops, as does the temperature. The molecules condense in a steamy fog over the cup, which lowers the tea's evaporation rate from the surface. Blowing replaces the hot, moist air with cooler, drier air, which then increases evaporation. Stirring will help to cool the tea by speeding up the process of convection, which brings the hottest liquid at the bottom of the cup up to the top. Creating a vortex through stirring will also increase the surface area to boost evaporation and cooling. ***ED***



PAD SCANLON, VIA EMAIL

WHY CAN'T MARINE ANIMALS SURVIVE IN FRESH WATER?

If you plopped a marine fish in fresh water, it would start absorbing lots of water across its gills. It wouldn't take long for it to get into trouble with the balance of water and salt in its body. It might even swell up! This is because their bodies are more salty than fresh water, so they absorb water via osmosis. Freshwater fish face this same problem, but they're adapted to get rid of water quickly – mainly by peeing a lot. Some fish, like eels and salmon, move between sea and fresh water by altering their biology, but it takes a lot of energy and time to switch from sea and freshwater living. ***HS***

GETTY IMAGES, ALAMY ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT

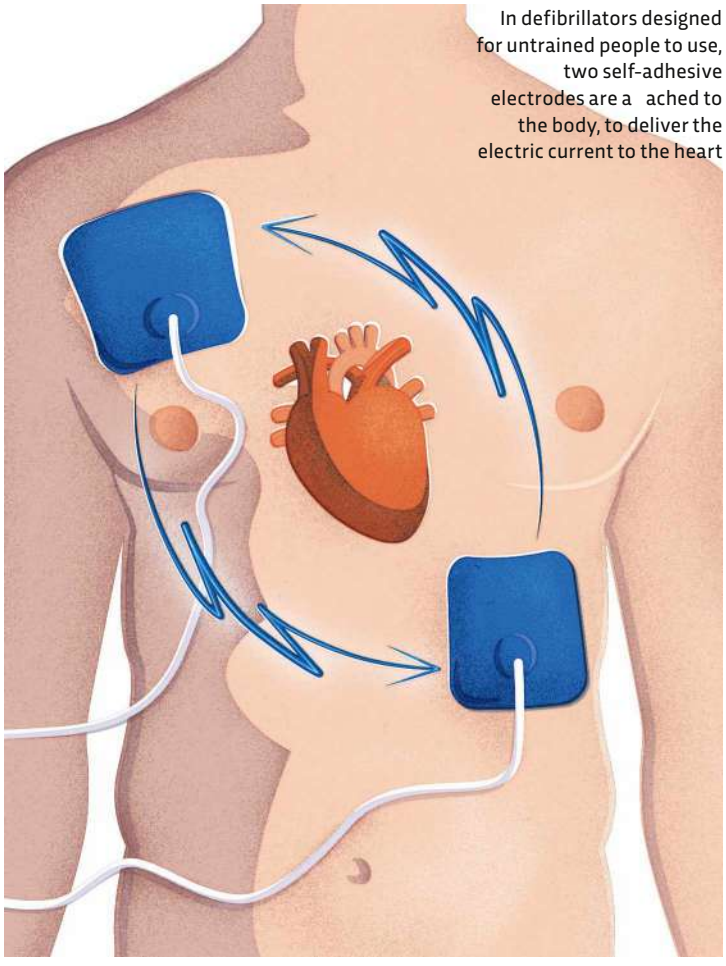
FELICITY BROWN, VIA EMAIL

HOW DOES A DEFIBRILLATOR WORK?

The sinus node of the heart is its natural pacemaker. It sends an electrical impulse to make the heart muscles beat in rhythm. Cardiac arrest is usually caused by a life-threatening change in the rhythm of the heart (known as dysrhythmia).

When the rhythm of the heart goes awry in cardiac arrest, the defibrillator delivers a dose of electric current to the heart. The process is not fully understood, but this current depolarises a large amount of the heart muscle, which ends the dysrhythmia. Once this happens, the pacemaker of the heart can re-establish a normal rhythm. If the shock delivered by the defibrillator isn't strong enough, the heart might not completely repolarise, and the abnormal rhythm continues. Defibrillators monitor the new heartbeat and might advise the user to deliver another shock.

A common misconception is that defibrillators will restart a heart that is flatlining (known as asystole). But this isn't true; once the heart is unable to create its own electrical pulse, a defibrillator will not work. Defibrillators do not jump-start the heart like jump-starting a car; they reset the natural pacemaker, like rebooting a computer. They are straightforward for anyone to use, and it's worth remembering that they don't typically allow the user to administer a shock if a 'shockable' rhythm is not detected – so you can't go far wrong, and speed is of the essence. ***NM***



In defibrillators designed for untrained people to use, two self-adhesive electrodes are a ached to the body, to deliver the electric current to the heart

NAT RE'S WEIRDEST ANIMALS...

THE HAMMERHEAD WORM

If the writers of *Stranger Things* Season 5 are looking for a new monster, they need look no further. This predatory flatworm, native to tropical and subtropical regions but now invasive worldwide, stalks and then kills the good guys – aka earthworms – with grisly aplomb.

Sensory organs on the underside of its unusual hammer-shaped head help the worm to detect its prey, which it then pins down with its head and body. The predator's mouth, which is located halfway down its body, opens wide, and the back portion of the mouth extends forwards to form a sheet which then clamps around the earthworm. Digestive enzymes are secreted, turning the earthworm's body into a tasty soup, which is then sucked up by the predator. When the job is done, any undigested material exits the worm the same way that it entered. Yes, that's right, the hammerhead worm's mouth is also its anus.

Like all good Netflix villains, the hammerhead worm is also toxic. At least two species produce a neurotoxin called tetrodotoxin, which they use to help subdue prey up to 100 times their own mass. They're also relentless. Chop them into pieces, and the feisty worms regenerate, making them seemingly immortal... unless you are familiar with the hammerhead worm's Achilles heel, which is, in fact, just a dip in soapy water. So maybe they're not so scary after all! ***HP***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

ARE BIG HEADS SMARTER?

Well, bigger heads do house bigger brains. And, at least based on the popular imagination, you'd think this would be an indication of greater intellect. Just look at the ultra-intelligent, bulbous-headed character Megamind (right), from the movie of the same name. As with many neuromyths, there is a grain of truth to all this – among humans, brain size and intelligence (as measured by IQ tests) are correlated, albeit modestly (estimates place the correlation at around 0.3 to 0.4, where 1 would be a perfect correlation).

But of course, correlation does not imply causation and there are many reasons to be careful about how we interpret the link. For starters, the modest correlation is based on an average of many people, and head/brain size will tell you nothing about a particular individual's intelligence (bear in mind that Albert Einstein's brain size was unexceptional, perhaps even on the small side).

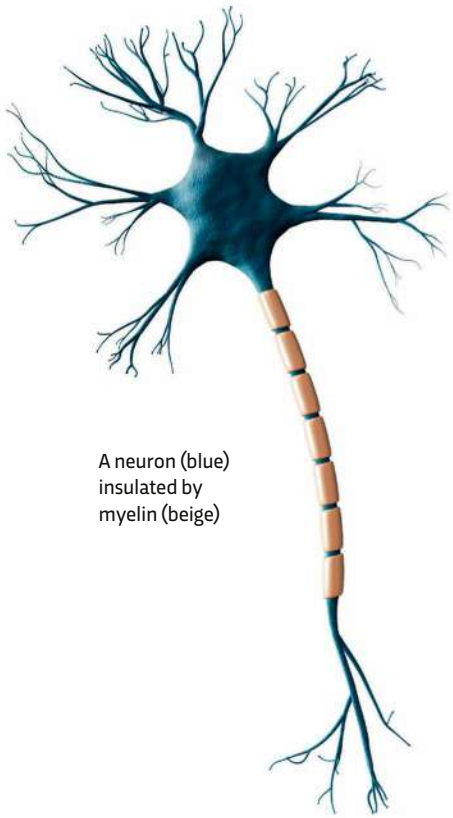
Consider too, that many animals have brains that are dramatically larger than human brains and yet we do not consider them anywhere near as smart as we are. For instance, elephants and whales have brains that are about six times as large as ours. At the other extreme, there are many animals capable of feats of intelligence in spite of having tiny brains – take the bumblebee, which can memorise the location of countless flowers over an area of several square miles.

Most experts agree that for intelligence, what's more important than overall brain volume is neuronal efficiency (how quickly and reliably neurons communicate with each other) and the nature and extent of the connectivity between key brain regions. *CJ*

ADVITA MITTÉ, AGE 11, SINGAPORE

HOW DOES MY BRAIN DIFFERENTIATE THE DIFFERENT LANGUAGES I SPEAK?

Human language is a complex phenomenon, and many different areas of the brain must cooperate together. Broca's area and Wernicke's area are two parts of the brain that we know control speech and language comprehension respectively, but many other areas are involved as well, including the hippocampus and the cerebral cortex. Recent research has suggested that the brains of people who are bilingual must take extra care to keep the nerve signals related to the different languages separate. They do this by adding extra myelin to insulate the neurons, and it has even been suggested that this might offer some protection from neurodegenerative diseases such as multiple sclerosis. ***LV***



A neuron (blue) insulated by myelin (beige)

TIM STEPHENS, VIA EMAIL

IS MARMITE GOOD FOR YOU?

Marmite haters are missing out on a healthy treat. For those that like or love the taste, the spread's only downside is its high salt content. Made from leftover brewer's yeast, Marmite contains boosting levels of the B vitamins thiamin, riboflavin and niacin, which nourish the nervous system and help the body to release energy from food. Folic acid and vitamin B12 help to make red blood cells. A 2017 study at the University of York found that Marmite's B vitamins may increase levels of a brain-calming neurotransmitter. Marmite is also rich in magnesium, which has a raft of functions in the body and may improve sleep quality. ***ED***

GETTY IMAGES X2, ALAMY X2 ILLUSTRATION: DANIEL BRIGHT

GAVIN WOOD, VIA EMAIL

WHAT IS WEB3?

The internet is made from the computers in the world that are networked together, from laptops to tiny sensors. The World Wide Web is the software we run on the internet to help us navigate, find and use resources or 'content' – data files that might be anything from videos to text documents, stored on all the computers. In the early days, most websites were static, fixed pages. The transition to Web 2.0 and dynamic content occurred at the beginning of the century. Now pages could change in response to user input, and concepts such as blogs and wikis enabled users to create new content. This evolved into new media, as audio, photos, video and gaming became integrated into the web. Yet critics began to question the dominance of today's web by a small number of 'big tech' companies who, while under the guise of providing free services, actually collect your private data and exploit it for vast profit.

Web3 is said to be the third great evolution by those who hope for a more secure and decentralised web. Making use of blockchain, cryptocurrency and NFTs, some hope that Web3 will provide the privacy, scalability and security that is currently missing. Web3 is attracting billions in investment, but it is fuzzily defined. Perhaps it will involve 'decentralised finance' without any need for banks, but then how to regulate it and give consumers protection from fraud? Perhaps it will involve 'decentralised autonomous organisations' – virtual companies that operate more like computer programs instead of following rules set by specific governments. Perhaps it will use 'self-sovereign identities', where you prove your identity with cryptographically secure 'verifiable credentials'. Web3 is generating excitement, but it has its critics. As it relies so heavily on crypto, and cryptocurrency solutions are largely consolidated into a small number of big players, the new web may end up resembling the old web – centralised and dominated by big tech.

Web3 is not the only vision of the future of the web. There is another idea, confusingly called Web 3.0, imagined by Tim Berners-Lee, the creator of the original web. Unlike Web3, Web 3.0 is not about blockchain – instead, the idea is to ensure every resource on the internet is identifiable, traceable and readable by computers in one giant web of meaning, or Semantic Web. He has also created the idea of decentralised social applications, where users own their personal data and can choose exactly who can access it. Berners-Lee's ideas are about equality and sharing of information freely, while respecting privacy of users. There are fewer buzzwords. Is it for these reasons that tech companies seem rather less enamoured by his vision? The slower uptake of this pioneer's ideas seems a shame since they may resolve many of the concerns for Web 2.0. ***PB***

ELLA MCGREGOR, EDINBURGH

HOW DOES ECHOLOCATION WORK?

With its built-in sonar, honed through millions of years of evolution, the bat is the undisputed poster child of echolocation. This furry, flying critter shouts into the void, and then listens to the echoes that bounce back from objects in the darkness. Echolocation helps the bat to navigate, and to chase and snatch prey, such as moths, straight out of the sky. Most of the world's 1,400 bat species use echolocation. They produce pulses of sound, largely in the ultrasound range, high above the limits of human hearing. Most bats contract their larynx muscles to make the clicks via an open mouth, but some species use other body parts. Leaf-nosed bats make calls through their elaborate noses, while some fruit bats make clicks by flapping their wings.

As the bat closes in on its prey, the pulses increase in frequency to more than 160 clicks per second. The returning echoes then help the bat to determine the size, shape, texture, distance and direction of the prey or object. At up to 140 decibels, the shrieks are also incredibly loud. Just before it calls, the bat contracts its middle ear muscle, effectively dialling down its hearing, so the mammal is not deafened by its own cries. The situation is then reversed almost instantly, so the echoes can be detected.

Toothed whales, including dolphins and porpoises, also echolocate, as do certain birds and small mammals, such as some tenrecs and shrews. The strategy makes sense for species that are active at night, or that live underground or deep in the ocean, where visual cues are limited. ***HP***

DEAR DOCTOR...

MENTAL HEALTH QUESTIONS DEALT WITH BY OUR EXPERTS

WHY DOES IT FEEL SO GOOD TO SET THE WORLD TO RIGHTS WITH A FRIEND?

When you have a good old chinwag with a friend about the problems of the world and how to solve them, the experience is psychologically satisfying on many levels. For starters, as we're all too aware from these last few years, global events such as pandemics and wars can be incredibly anxiety-provoking. When you spend time discussing potential solutions, you are, in a sense, giving and receiving emotional support. This can be both comforting and cathartic – even if it's all hypothetical. Moreover, if you have this chat with a close friend and you find yourselves in agreement about how to fix the world, the experience will also serve to strengthen your relationship. In a way, you are enjoying the known friendship-boosting benefits of gossiping, but with the focus of your chat zoomed out to the international scale. After all, we tend to be attracted to people who hold similar values and views to our own. So, if the conversation leaves you with a sense that you and your friend share the same world view, you're likely to come away with a satisfying sense of closeness and belonging. What's more, airing your political values and beliefs – and having them validated by your friend – can help shore up your own sense of self. Psychologists call this your 'self-concept clarity', which is good for your self-esteem. ***CJ***

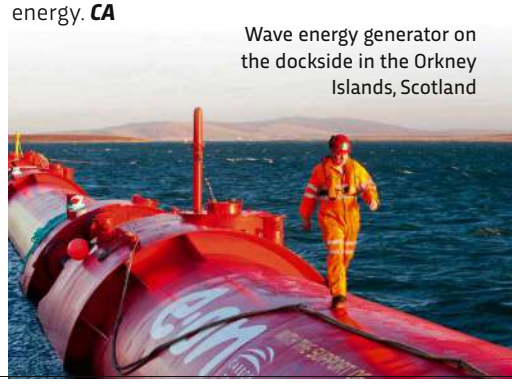
KYLA BALL, VIA EMAIL

WHAT'S THE DIFFERENCE BETWEEN WAVE ENERGY AND TIDAL ENERGY?

You may have learned at school that the ocean's tides are caused by the Moon's gravitational force pulling water towards it as it orbits the Earth, while waves are caused by wind blowing across the ocean's surface. All that movement means ocean waters contain a huge amount of kinetic energy, and scientists and engineers are developing ways to capture these renewable resources.

Tidal energy can be harnessed using underwater turbines, which are similar to wind turbines but with shorter, stronger blades. Water flowing through the turbine turns the blades, which turns a generator, producing electricity. Tidal turbines work best in narrow passages of water, which naturally channel tidal energy through the turbines. For example, one of the world's largest collections of tidal turbines can be found between the Scottish mainland and the Island of Stroma, capturing the tides flowing between the Atlantic Ocean and the North Sea. Another approach is to use natural or artificial barriers to trap water at high tide and redirect the flow through turbine-filled channels as the water returns to the ocean.

In contrast, wave energy converters can be placed on the shoreline or in the open ocean, and often use floats that rise and fall with the waves to compress a hydraulic piston, turning a generator. Alternatively, shoreline devices can direct incoming waves into a narrow column, forcing air through a turbine to generate electricity. There are still technological challenges to overcome, but the oceans could one day provide huge amounts of reliable, renewable energy. ***CA***



Wave energy generator on the dockside in the Orkney Islands, Scotland

SAMMY CLARKE, VIA EMAIL

WHAT IS TETRACHROMACY AND HOW DO I KNOW IF I'VE GOT IT?

Tetrachromacy is a rare type of colour vision that allows people to see colours that other people can't.

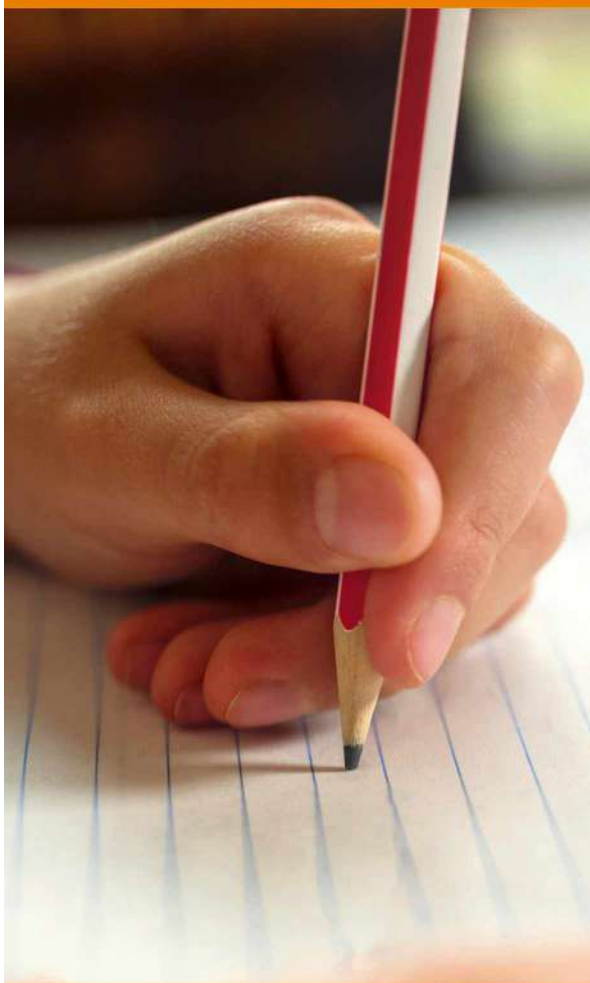
Most people's colour vision is 'trichromatic', meaning their colour vision depends on three types of specialised cells in the eye, called cones. These cones are often referred to as blue, green and red cones, depending on the wavelengths of light that trigger them. In comparison, 'tetrachromats' have a fourth type of cone, which is most sensitive in the yellow-green region of the visible spectrum. While those of us with three of these receptors have the ability to distinguish around a million different colours, tetrachromats are thought to see an estimated 100 million.

It is thought that only women can be tetrachromats. The gene for cones lie on the X chromosome. A woman who has two X chromosomes can carry the normal genes on one of her X chromosomes and an anomalous gene on her other one. This genetic pattern enables her to express four types of cone.

A woman might carry the gene is if she has a son (or father) with a slight colour anomaly (such as very mild colour blindness). We can predict with some confidence that the milder the son's (or father's) colour anomaly, the better chance there is for the mother (or daughter) to see the world in different colours.

Despite lots of claims by various websites, there's not a particularly reliable test to work out if you have tetrachromacy – the definitive way is through a genetic test. ***NM***

QUESTION OF THE MONTH



SARA BJELANOVIC, AGE 14, LONDON

WHY DOES WRITING MY OWN NOTES HELP ME LEARN THINGS? DOES IT MAKE A DIFFERENCE IF I WRITE OR TYPE?

In his book, *Why Don't Students Like School*? psychologist Prof Daniel Willingham says that "memory is the residue of thought". We remember the things we think about, not necessarily the things we are told. When you write notes in your own words, you force yourself to reframe someone else's ideas into a form that you can concisely express on paper. This mental effort increases the chance of this information being transferred to your long-term memory later. Many studies have found that handwritten notes, particularly those with arrows, diagrams and margin doodles, improve information retention. Typing is quicker, but it is too repetitive and mechanical to stimulate your focus and attention. *LV*

WINNER

The winner of next issue's *Question Of The Month* wins a **Performance Pack from Tile** worth £54.99. It contains a Tile Pro to attach to your keys or rucksack, and a Tile Slim to put into your wallet or notebook. Tile trackers sync to an app on your phone, so you can easily find your misplaced belongings.
uk.tile.com

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

ALAMY, GETTY IMAGES X2 ILLUSTRATION: DANIEL BRIGHT

THE EXPLAINER

WILDFIRES

WHERE DO WILDFIRES OCCUR?

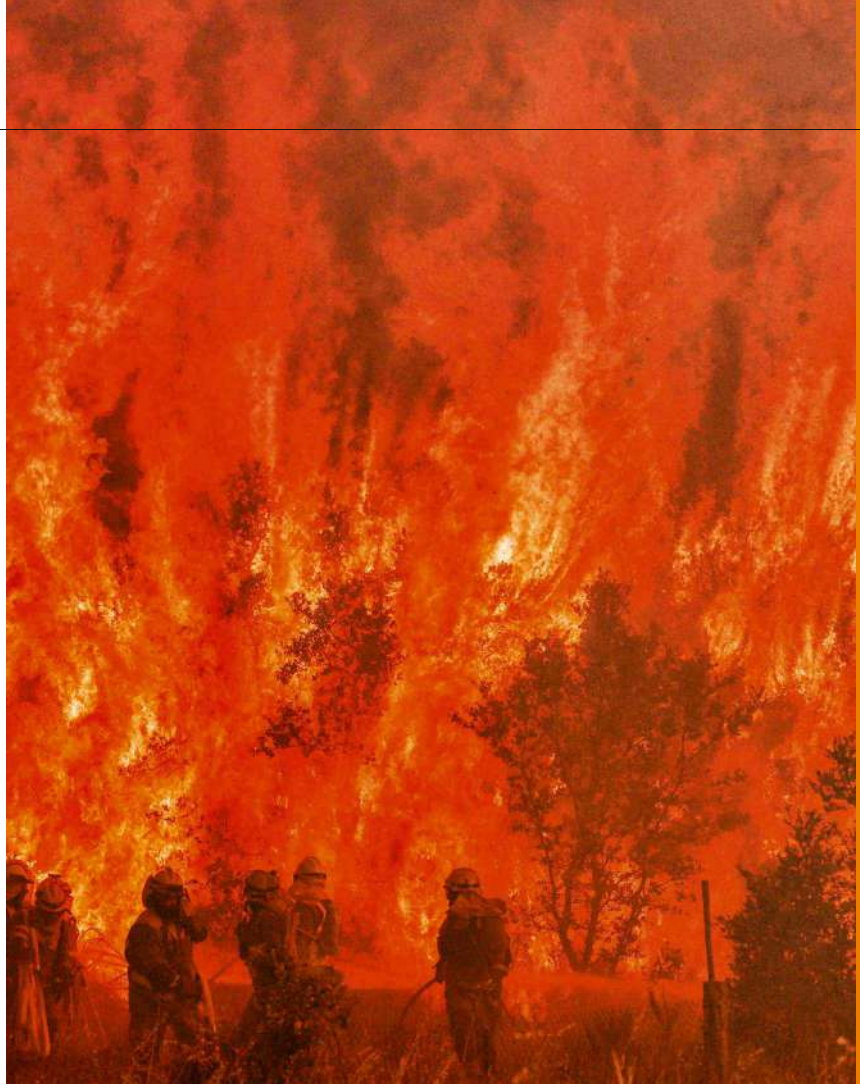
Wildfires have occurred on our planet ever since terrestrial plants started appearing over 400 million years ago, in the period of Earth's history known as the Silurian. While certain regions are well known for them, such as Australia, Greece, the Amazon and the western USA, they actually take place on most areas of land around the globe. Wildfires can even occur in some of the most unexpected places, such as the Arctic Circle, where so-called 'zombie fires' can burn peat and permafrost under the ice, persisting throughout the cold seasons. The more well-known events, such as the devastating fires in Turkey last summer, are generally associated with the fast burning of large areas of forests. These can be clearly seen as smoke plumes from a distance, and are even visible from space.

Wildfires can wreak havoc on everything in their path, be it humans, animals or buildings. In some parts of the world the biodiversity loss can be catastrophic. But in other cases, the natural occurrence of wildfires is so ingrained that some species have evolved to work with it. For example, some plants' seeds require exposure to fire in order to sprout.

WHAT ARE THE CONDITIONS FOR A WILDFIRE TO START?

Wildfires start when the vegetation is ignited, with drier vegetation making this process much easier. The ignition can be either human-caused (from barbecues, arson, or discarded cigarettes) or natural (from lightning strikes or volcanic eruptions, for example). A lot of fires are caused by humans, which is why many countries have laws on what months people are allowed to have a barbecue, even on their own property. These things on their own are not normally enough to allow the fire to spread. The moisture accumulation over the preceding months, especially in soils, can help prevent spread. Likewise, the current humidity, or whether or not it is raining, are also critical. In some countries where wildfires spread rapidly, it is the wind that is doing the real damage – fuelling the fire with replenished oxygen, pushing the flames to adjacent vegetation, and spreading burning embers far and wide.

Forest fires can sometimes reach speeds of up to 11km/h, with smoke being particularly disorientating for anything in the vicinity of the fire.



ARE FIRES CHANGING DUE TO CLIMATE CHANGE?

Given the different weather types that inttuence fire risk, the links with climate change are complex. For many active wildfire regions around the world, fire risk is projected to increase, mainly driven by elevated temperatures, but also from decreasing humidity. This combination is ideal for drying out vegetation, creating the perfect fuel for the fires.

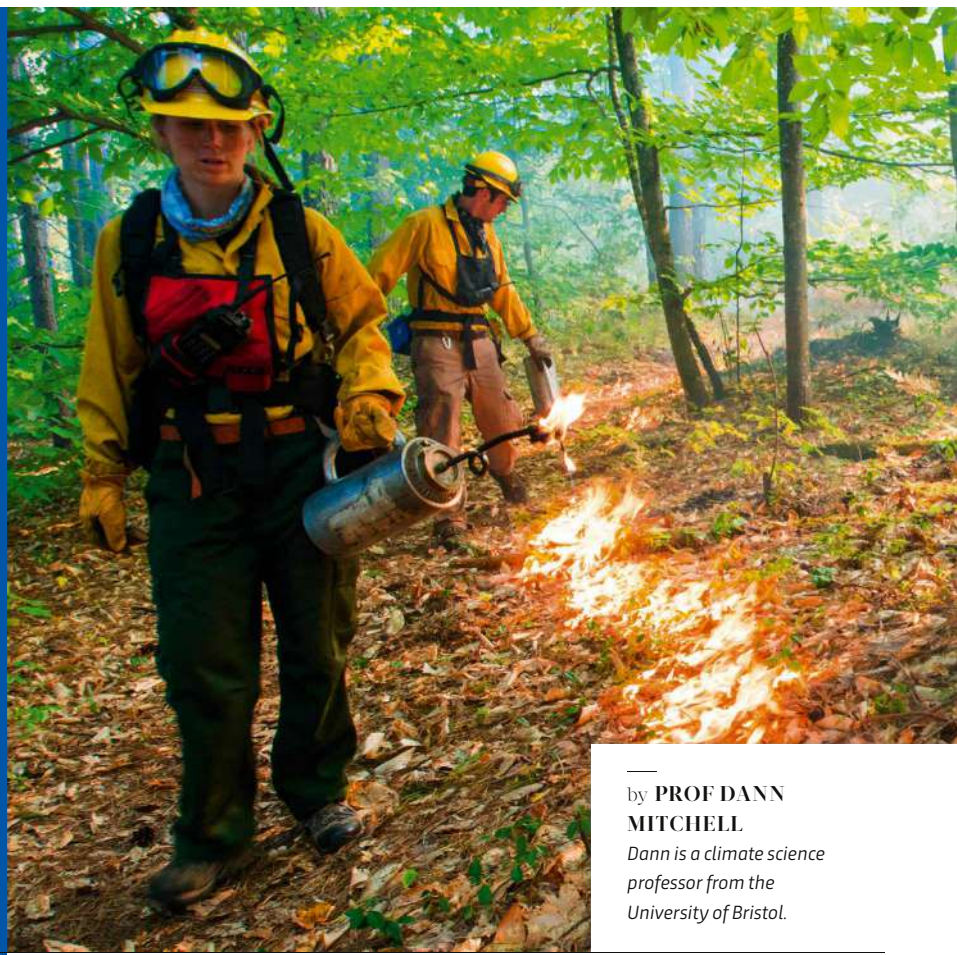
Wildfires tend to occur in summer, where temperatures are highest, but what goes on in the earlier seasons can also be important. The amount of vegetation, or fuel, is also critical, and we expect this to increase for many parts of the world, as atmospheric carbon dioxide makes plant photosynthesis (and therefore growth) more efficient.

Even today, and all else being equal, it is believed that climate change could be doubling the land that is being burned from wildfires. On around a quarter of vegetated land, the wildfire season has also increased, due to a combination of increasing droughts and raised temperatures. When trees burn, they release their stored carbon into the atmosphere, and this can cause up to a third of ecosystem carbon emissions. This is a vicious negative feedback cycle, whereby climate change is causing more wildfires, which in turn leads to more climate change.

IS CLIMATE CHANGE THE BIGGEST FACTOR TO CHANGES IN WILDFIRES?

Despite climate change leading to an increased risk of wildfires, satellite data from the 1990s onwards has actually shown that the global area burnt from wildfires has gone down. A large part of this decrease is due to forested areas being converted to farmland. It is therefore known that societal interventions are at least as important for wildfires as climate change is, but for many regions around the world, the interplay between each factor is not clear.

For some particularly well-studied hotspots, such as western North America, there is strong evidence that supports climate change as the dominant driver of the increases in burnt land. But for most other regions around the globe, this is not the case, and it is believed that natural climate cycles, deforestation, fire suppression and agricultural burning can play a more dominant role. The human interventions here can be particularly important if the right policies are in place, and the more that climate change leads to increases in wildfires, the more we will need these societal interventions to combat that.

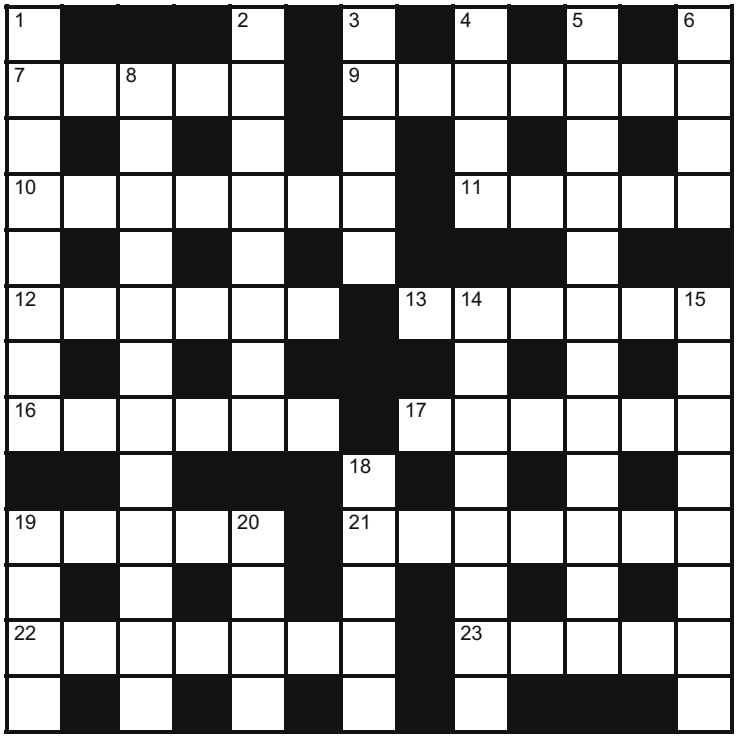


GETTY IMAGES X3, ALAMY

by **PROF DANN MITCHELL**
Dann is a climate science professor from the University of Bristol.

CROSSWORD

PENCILS AT THE READY!



ACROSS

7 Maid managed, with time, to confess (5)
9 New respect for spirit (7)
10 Delayed getting daughter associated (7)
11 Fast to get under the influence (5)
12 Vision makes the old turn fuel off (6)
13 Punctual cue (6)
16 Vegetable new to land (6)
17 Point – something to aim at for Victor (6)
19 Supercharger includes somewhere to sit (5)
21 Runaway gets free movement, holding universal keys (7)
22 Steady income for dairy farmer? (4,3)
23 Elgar doesn't start changing old tempo (5)

DOWN

1 British lad shook head to show lack of cover (8)
2 View of arrogance (8)
3 Whisper to a team (5)
4 Wager has a pulse (4)
5 Theatrical chap gets a lively fellow to change gear (5,7)
6 Partially invested in underwear (4)
8 Symbol making Mediterranean islander angry (7,5)
14 Iran negotiated to decline measure of water (8)
15 Attacked, excited (6,2)
18 Monarchy initially collapsed, worn out (5)
19 Wolves put in a suitcase (4)
20 Reporter has a bad cough (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

MEET THE ANIMAL ARCHITECTS

GETTY IMAGES

PLUS

GUIDE TO NAPPING

The best way to get 40 winks.

DYSON SPHERES EXPLAINED

No, they're nothing to do with vacuum cleaners.

ON SALE 17 AUG

SF

SUBSCRIBE TO MBUK

BRITAIN'S BEST-SELLING MOUNTAIN BIKING MAGAZINE

AND GET YOUR FIRST 3 ISSUES FOR JUST £5!

WHY SUBSCRIBE?

• Try your first three copies of *Mountain Biking UK* for just £5 • **Continue to save 30%* on the shop price, paying £24.99 every six issues by Direct Debit** • Every magazine will be sent hot off the press and delivered straight to your door • **Get access to exclusive offers and competitions with our Subs Zone** • You'll never miss an action-packed issue or supplement again!

TO SUBSCRIBE...

http://buysubscriptions.com/MBH22

OR call our hotline on **03330 162152**, quoting code **MBH22**

Lines are open 8am to 6pm weekdays, 9am to 1pm Saturdays

TERMS & CONDITIONS: Three issues for £5 offer is only available to UK residents paying by Direct Debit. Your subscription will start with the next available issue. After your first three issues, your subscription will continue at £24.99 every six issues. *Mountain Biking UK* magazine is published 13 times a year. If you cancel within two weeks of receiving your second issue, you will pay no more than £5. UK calls cost the same as to other standard fixed-line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages, calls from mobile phones cost between 3p and 55p per minute. * 30% saving is based on buying six issues at the full UK shop price.

Offer ends: 31 December 2022

POPCORN SCIENCE

Could fire-breathing dragons exist?

It's all a question of GCSE chemistry and fire-resistant materials...

by **STEPHEN KELLY**

The prequel to *Game Of Thrones*, *House Of The Dragon*, tells the story of House Targaryen, masters of that most fantastical of creatures: giant, fire-breathing dragons. But are dragons really as outlandish as they seem? Surely no animal could grow so large and fly, or evolve the ability to spit fire? Henry Gee, evolutionary biologist and author of *A (Very) Short History Of Life On Earth*, says the idea is "not quite as daft as you might think".

He cites the bombardier beetle as an example. "It synthesises a mixture of hydrogen peroxide and hydroquinone," he says. "When the beetle is threatened, it puts the mix into a combustion chamber, and enzymes provoke the chemicals to react, producing a toxic substance called benzoquinone. It then squirts this boiling-hot liquid into the eyes of an assailant. When you think about that, producing fire is no big deal."

Gee has a convincing theory for how a dragon would be able to burn you alive. "My scheme would be the biological synthesis of a substance that ignites spontaneously when forcefully ejected into the air. And there is such a substance: diethyl ether."

As Gee points out (with the obvious caveat that you shouldn't try this at home), ether is fairly simple to make – all you do is warm alcohol in the presence of sulphuric acid. "Alcohol is produced by all sorts of organisms, and living organisms produce sulphates, so it's not too big a stretch to say that they might produce sulphuric acid," he says. "I could imagine that there would be modified salivary glands in the dragon's mouth containing colonies of microbes that would do just this."

Ether also has the relatively low flash point of 45°C. "It's so ignitable that a dragon could squirt liquid ether across its teeth and it would burst into flame." The dragon's skin would need to be fire-proof, of course. "There's no reason why dragon scales wouldn't contain something like borax," says Gee, referring to the substance used in many fire-retardant materials.

There are, however, potential issues with the idea of spewing fire from your mouth. "There would have to be some sort of lining of the gland to prevent the dragon from poisoning itself," says Gee, who points out that there are many animals capable of carrying poison without poisoning themselves. "You'd also have to watch out for buildup of insoluble sulphates, which could clog up the glands and cause pain and disease." Gee maintains, however, that there is no biological reason why creatures couldn't evolve to breathe fire. "Just because it hasn't happened, it doesn't mean that it's impossible."

What Gee is more sceptical of is the idea that dragons the size of those in *Game Of Thrones* would be able to take off from the ground.

"If you watch swans or geese in their run-up, you'll know that if they were any bigger, they wouldn't manage it," he says. For comparison, Gee cites the dragon's spiritual kin: dinosaurs and ancient flying reptiles. "Some pterodactyls were as big as small planes, but they wouldn't have been much good at flapping. Dragons are so much bigger." Indeed, Gee theorises that some dinosaurs that were small enough to fly evolved to such a large size that flight became impossible.

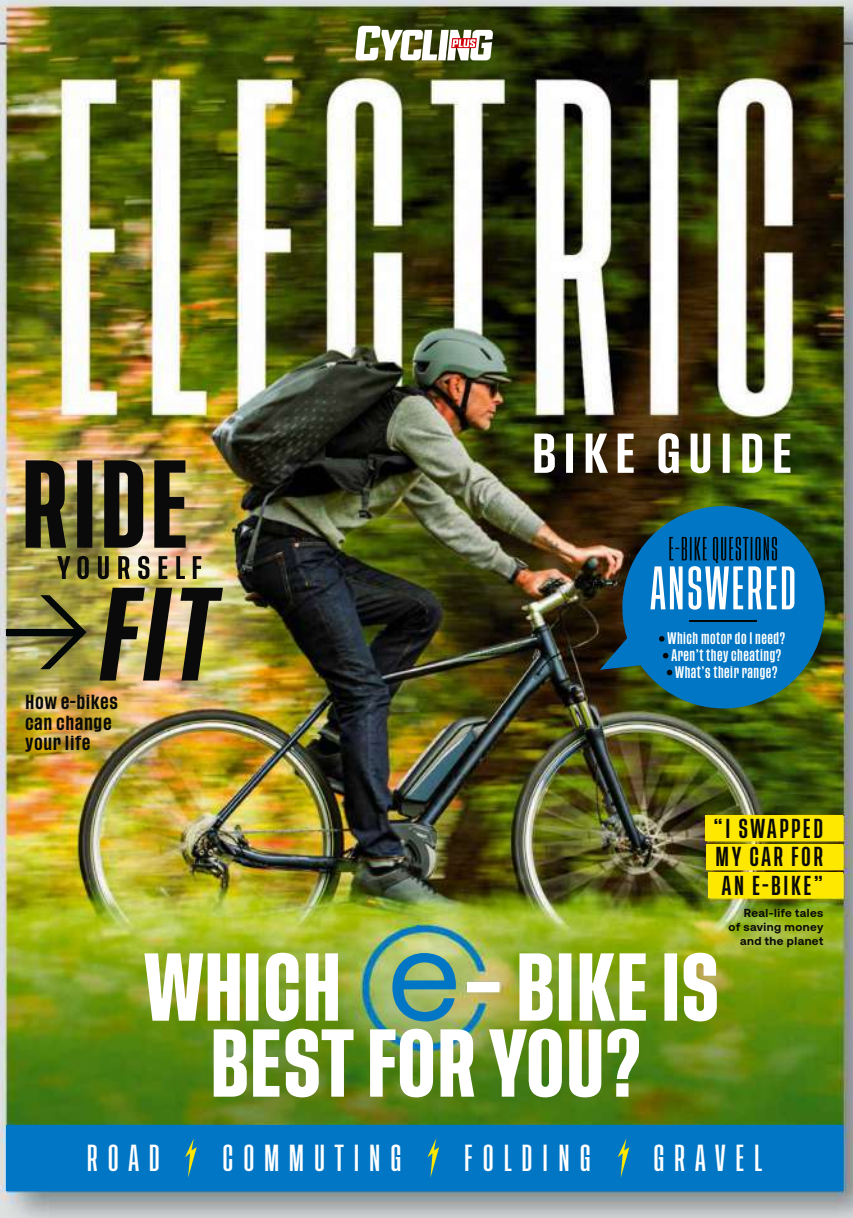
"Who knows," he says. "Maybe some of the later, larger dinosaurs were dragons that fell to Earth." **SF**

VERDICT

The bombardier beetle has *nearly* sussed the biology, and that's good enough for us! Plus, we just really, really like dragons.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATIONS: ADAM GALE MAIN ILLUSTRATION: MARK FRUDD


CYCLING PLUS
ELECTRIC
BIKE GUIDE
RIDE YOURSELF FIT
How e-bikes can change your life
E-BIKE QUESTIONS ANSWERED
• Which motor do I need?
• Aren't they cheating?
• What's their range?
"I SWAPPED MY CAR FOR AN E-BIKE"
Real-life tales of saving money and the planet
WHICH e- BIKE IS BEST FOR YOU?
ROAD COMMUTING FOLDING GRAVEL

FROM THE MAKERS OF CYCLING PLUS MAGAZINE

ELECTRIC BIKE GUIDE

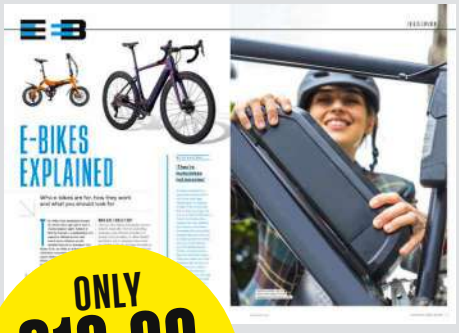
Everything you need to know about buying, maintaining and riding an electric road bike

INSIDE THIS SPECIAL-EDITION MAGAZINE YOU'LL FIND:

→ Easy-to-follow explainers on ebikes, from the controls and frame design to the battery, motor and parts

→ How to choose the right ebike for you and your cycling needs

→ Tips on getting the most from an e-powered bike, riding smart and adjusting your technique from a non-powered bike to electric



ONLY £10.99 INCLUDING FREE DELIVERY!

Whether you plan to ride in an urban environment, on gravel or on the road, there are plenty of ebike reviews and the best ebike-specific gear and kit to get the right setup for you

ORDER YOUR COPY TODAY

www.buysubscriptions.com/electricbikeguide2022

or call 03330 162 138 and quote 'Electric Bike Guide 2022 Print1'

Lines are open 9am-5pm weekdays. Overseas please call +44 (0) 1604 973 746
UK price is £10.99 with free delivery. EUR price £12.49, ROW price £13.49
All orders are subject to availability. Please allow up to 28 days for delivery

UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff).
Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Please allow 28 days for delivery

HONDA
Miimo
BUILT TO LAST
WITH A BEST IN CLASS WARRANTY
Miimo
HONDA
Our Honda Miimo intelligent robotic mowers carefully navigate your lawn, only cutting where and when you want them to. Built with unrivalled quality and legendary reliability, you can relax and enjoy a beautiful, healthy garden every day, year after year.
UP TO
5
Year Warranty
HONDA
Domestic Use
ENGINEERING FOR Life
For more information, and to find your local dealer, visit: honda.co.uk/miimo